# JOURNAL
## OF THE
# AMERICAN WATER WORKS ASSOCIATION

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## Contents




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# AMERICAN WATER WORKS ASSOCIATION





Vol. 34 | September 1942 | No. 9


## A.W.W.A. Objectives—1942

EVERY water works man is aiming for Victory and wants to find ways to do his job well and play his part in the campaign. Here is your banner. Fight under it!

### *Save, Stretch and Share to Win the War!*

**Save!**

What does saving mean in water works? First, it means a stop to leaks in mains. Did we hear you say "there are no leaks in our system?" Sorry Sir! there *ain't* no such system. Its only a question of how big they are. One critical city in the East recently found one leak that amounted to nearly 10 per cent of the daily production. Think what that saves in coal and pumping when it is stopped. Don't kid yourself! There are leaks in your system that *are* worth stopping. So tighten up the mains.

Your domestic customers will be glad to play their part in a fight against waste of water. Reminders of the amount of water a dripping faucet can waste can go out with the bills and bring good results. Naturally there is danger of *over*doing such a campaign. You could waste manpower hunting for little faucet leaks—but making all your customers conscious of their part in saving water is worth while—if not overdone.

Are there war industries in the town? There is your number one spot for an anti-waste campaign. A new, rapidly expanding industry, built in a hurry, staffed in a hurry, is full of wasteful habits. Such people should respond quickest of all to your appeal. Its Uncle Sam's money that pays

their water bill and its Uncle Sam's coal and chemicals and metal that you save if they save.

How about saving through salvage? Is there a man in this country today who does not know that there is critical need for scrap iron, scrap brass and copper and scrap rubber? Play your part in the local salvage drive. Look into your storehouse! Is there a bit of equipment there that you have not used for years and probably never will use again? Don't be an old fuddy-duddy who keeps things just because he can't make up his mind to get rid of them. Clear out that junk! That's saving that serves the war effort 100 per cent.

**Stretch!**

What do we mean—stretch? Well, believe it or not—one thing to stretch is pipe! But you say water pipe won't stretch. Yes it will. It (nine times out of ten) can do more work than it is now doing. How does a water pipe work? By delivering. Suppose that there are lines of pipe in your city that have tuberculated so that they will deliver only 50 or 60 per cent of their rated capacity or additional pumping pressure is required to maintain delivery. You can stretch that line by cleaning it out. There are some on-their-toes engineers in this country who consider the necessity of cleaning certain lines just as much a part of spring as the coming of the first robin. They figure the costs from every angle—and clean the pipe. That is one way to stretch. Keeping up efficiency of boiler or power and pumping plant is another. No plant is too small to aim at efficiency. Reread Homer Beckwith's 1939 A.W.W.A. JOURNAL story of "A Simple Method of Testing Centrifugal Pumps." Try out your pumps along the line he suggests—then tune them up. Coal and electric power are going to be priceless during the next few months. Use them efficiently!

Have you a filter plant to stretch? It can be done. How many "out" hours are charged up on your log sheet? Why? How far short of rated capacity are you operating those filters? Can you justify anything short of rated capacity of your existing plant if you are thinking of asking for an extension to the plant? Prepare the water better by intelligent and adequate use of coagulants. If chlorine at the super or breakpoint rate will serve to speed up production as well as quality of water, use it. Discuss your problem with your chlorine supplier. There is good reason to believe that if the question is more chlorine *vs.* more filters, the way can be found to get more chlorine for the defense-related water plant. Our friends of the great Metropolitan Water Board of London now are frank to say that it was things of this sort that made it possible for them, during the blitz, to produce the added amounts of water

needed and keep the quality of it good. We do not face the blitz—today. But if more efficient use of our present equipment (and no new filters) will help keep tomorrow's blitz away, why not operate at full efficiency?

**Share!**

Finally—what about sharing? Water works men in many states have been ready for months to share materials, men and equipment if a bombing came. They call it planning for mutual aid. But some of them have planned in the way that you send flowers to a friend—when he's dead. The bombing hasn't come—but the shortages in pipe and valves and all the rest of those things have come. The shortage, however, does not exist in the average water works plant. Our people have taken care of that reserve against bombing pretty well. In fact some people in authority think that they have done it too well. They point out that the inventories of repair materials in the large water plants are 20 per cent above the allowable limit. They also point out that today there are ordnance plants, navy depots and dozens of military production centers that cannot get into operation today for want of water pipe and the like.

There isn't enough surplus in our hands to fill all those needs—by no means. But there is today—and this is serious—there is today in the yards of American water works plants, a substantial amount of critical finished goods that could be spared today. By none of the rules of the War Production Board and by none of the British records of what is actually needed, can some of our water works now defend the excess inventory they have today. Hoarding helps Hitler whether it's sugar or cast-iron pipe. So get rid of your surplus inventory. Let somebody with a job to do today put it to work today. Strip your reserves down to what you had two years ago—and what is, we now know to be (on the average), all you need.

***Save, Stretch and Share to Win the War!***

Yours for Victory,

ABEL WOLMAN,
*President, A.W.W.A.*

LOUIS R. HOWSON,
*Chairman, A.W.W.A. Committee on Wartime Water Works Practice*

HARRY E. JORDAN,
*Secretary, A.W.W.A.*

August 7, 1942

# Water Service in Wartime London

***By Henry Berry***

*Herewith are presented six articles prepared by Henry Berry, Chairman of the Metropolitan Water Board of London, England, as a comprehensive study of wartime water works problems in the London metropolitan area. These articles have been issued as a series called "Water Service in Wartime," and include:*



*These papers have been made available for publication through the courtesy of the British Information Services, New York.*

## 1. Protective Measures of Filtration and Chlorination

The Metropolitan Water Board of London, England, supplies water to over seven million persons, the area of supply covering about 537 sq.mi. The whole of the County of London lies within its boundaries. The board has the honor to include within its area the seat of His Majesty's Britannic Government and many departments of state. It is the board's duty to maintain a supply of water not only for essential domestic consumption but also to meet the vital needs of the fire fighting services and the many industrial undertakings within the area, which are engaged on urgent work in connection with the war effort.

Fully aware of the gravity of its task, the board has undertaken extensive precautionary works involving large expenditure. Experience so far has amply justified both foresight and expenditure. As the war proceeds, fresh problems arise and it is necessary to keep every branch of activity under constant review in order to maintain the maximum degree of efficiency while ensuring that all economy possible is exercised.

## Precautions for the Protection of London's Water Supply

The water supply of London is derived from three main sources: the River Thames, about two-thirds; the River Lee, about one-sixth; and deep wells, about one-sixth. The quantity supplied varies between 250 and 410 mgd. The works comprise storage and service reservoirs, pumping stations, large filtration plants and some 8,000 miles of mains.

80 per cent of the water is derived from the polluted Rivers Thames and Lee

About 75 per cent of the raw water samples contain *Esch. coli* in 1 ml.

The water is stored in large reservoirs and undergoes bacterial purification by storage, the number of *Esch. coli* being reduced to about one one-hundredth of the original number.

The next stage is filtration, after which about 75 per cent of the samples contain no *Esch. coli* in 100 ml.

## Wells

The water is finally treated with ammonia and chlorine, after which over 99 per cent of the samples have no *Esch. coli* in 100 ml.

The well waters are easily purified, the only additional war measures having been the application of chlorine treatment to all well supplies and the duplication of facilities for chlorination at every well station by the provision of tanks for dosing hypochlorite solution should the gas chlorinators be damaged. It is most unlikely that gross pollution will gain access to a well as a result of enemy action.

The only incident in connection with well supplies which can be foreseen and which would not be covered by terminal chlorination is the possibility of flooding at certain wells, which are situated near rivers or polluted water channels, in the event of damage to the banks. Should this occur, pumping would be stopped as quickly as possible.

## Filtration Works

As has been noted, the river waters are heavily polluted. Prior to the war, the main lines of defense were:

1. Storage in reservoirs
2. Filtration through slow sand filters either alone or secondary to coarse filtration through mechanical "primary" filters.
3. Terminal chlorination. (Chlorination prior to filtration was also the practice at some works.)

Since the commencement of aerial attacks, however, the output from individual works has at times greatly exceeded the normal figures, owing to the demand for fire fighting and loss through fracture of mains. The

capacity of the filtration plant has, moreover, frequently been restricted through damage to filter beds and conduits. It has been necessary at times to work the remaining filters at rates in excess of those at which they may be expected to exert their maximum purifying effect.

Deterioration in the bacteriological quality of the water, which might have been expected to result from these conditions, has been prevented by the extended use of chlorination. By the universal application of pre-chlorination, i.e., dosing with chlorine before filtration, the pre-filtration waters have, with only occasional breaks, been brought to a state of bacteriological purity which might be held to render filtration unnecessary from the point of view of safety alone.

This contention would not be altogether justified, for there is always the possibility of the presence in the raw water of particles of fecal matter in which the bacteria would be protected from the action of chlorine. This possibility is increased when it is necessary to pass raw river water to the filters instead of stored reservoir water.

Nevertheless, the results achieved by pre-chlorination have been so good as to discount all pre-war ideas regarding permissible rates of filtration and, consequently, to justify the use of the filters chiefly as strainers, the primary function of which is to remove suspended matter as distinct from bacteria. At times of heavy demand or of damage to filters, the rate of filtration may, therefore, be increased to the maximum possible without deterioration in the quality of the filtered water.

Thus, pre-chlorination has added a fourth line of defense to the three—storage, filtration and terminal chlorination—which previously existed. This is a matter of the utmost importance, as it is firmly believed that reliance should never be placed upon one line. Should two lines be broken simultaneously, as has happened in the past, two still remain.

## Loss of Storage, Damage to Filters and Short-Circuiting of Filtered Water and Unfiltered Water Channels

All stored water is now pre-chlorinated and brought to a comparatively high state of bocteriological purity before it passes to the filters. To provide against the loss of storage and consequent necessity to pass raw river water to the filters, a high-capacity chlorination plant has been installed at all river intakes.

One danger of this is the possibility that raw sewage, containing particulate (visible particles) fecal matter will pass into the rivers above the intakes: This might negate the beneficial effects of pre-chlorination.

Strong representations have, therefore, been made to the British Ministry of Health, which has issued instructions that should restrict the practice of

passing untreated sewage into the rivers to rare occasions, if not entirely prevent it. Its occurrence, coincidently with failure of filtration through damage to filters as conduits, appears to be a danger against which no adequate protection can be given.

That the measures described have given a high degree of protection has already been amply demonstrated. Despite considerable damage to filters, conduits, etc., and the frequent use of unstored chlorinated river water, there has been no deterioration in the quality of the filtered water. As a result of pre-chlorination, the filtered water has, in fact, been purer than ever before.

### Measures Against Failure of Chlorination

Chlorination instruments have all been protected against blast, many of them by the construction of specially designed buildings. Damage to chlorination instruments has also been provided against by installing at every chlorination point, except at certain raw water intakes where it is precluded by physical conditions, tanks from which hypochlorite solution can be delivered to the filtered water.

These tanks are inspected daily and the setting of each delivery tap is checked. Merely by filling the tanks with hypochlorite solution they can be brought into action by the engine-room staff should the chlorination staff be incapacitated. The dose which they deliver cannot be adjusted accurately at night to the varying output of water. They are, therefore, set to the maximum output and some degree of overdosing with resultant tastes is inevitable. They remain in use only until daylight, when they are replaced by portable gas chlorinators, of which an ample supply is held in reserve at central points. These have been especially designed for use with or without a water supply and have been so adapted and fitted as to enable them to be brought into use, wherever they may be required, with a minimum of delay.

Two provisions have been made against failure of water pressure to chlorinators:

1. Suitable pumps have been installed in chlorination houses at key points. These draw their water from local sources and are started up immediately if water pressure from the main shows any sign of falling off.

2. At other places, the hypochlorite tanks can be brought into use pending the provision of portable pumps, a supply of which has been distributed at suitable centers.

At the majority of chlorination points duplicate or triplicate piped water supplies have been connected from different mains in addition to the precautions above.

It will be seen that, short of widespread demolition, which would almost certainly be accompanied by destruction of the pumping plant or the necessity to pump unfiltered water into supply, it is most unlikely that the water pumped from the works would become unsafe to drink except possibly as a result of the following combination of circumstances:

1. The presence of particles of fecal matter in the river water sufficiently large to prevent their disinfection by both the pre-filtration and the final dose of chlorine
2. Damage which would necessitate supplying unstored river water to the filters
3. Damage to filters or conduits which would permit unfiltered water to gain access to filtered water channels.

## 2. Precautions Against Pollution and Other Dangers

Since the commencement of fire-raids it has been realized that, if a works normally supplying a district should become damaged, it would not be sufficient to supplement the supply within that district by bringing in, from another works, a mere sufficiency of filtered water to satisfy urgent domestic needs. It might be necessary to provide a quantity of water much above the normal to meet the demand for fire fighting.

### Pumping Unfiltered Water Into Supply

In the event that quantities of water beyond the capacity of the existing filtration plant are required for the extinction of fires, or that damage is inflicted upon works or filters to such extent that their capacity would be insufficient to maintain a supply of pure water for domestic purposes, it has become the policy of London's Metropolitan Water Board to make up the deficiency by passing unfiltered water into supply. The necessity for such a course, *which has not yet arisen*, might well cause the gravest anxiety. It would be adopted only in case of most serious emergency.

The full implications of this procedure should be appreciated. They vary with the character of the water supplied to the works. Many works receive stored water from the large reservoirs, some of which ensure prolonged storage, but it is known that many of them do not give anything approaching the theoretical storage time, owing to the close proximity of the inlet to the outlet pipe. Nevertheless, it has been found in practice that the quality of the water drawn from the reservoirs is such that a high degree of purification can be achieved by chlorination with a dose which would not give rise to such serious taste as to make the water undrinkable.

It may, however, become necessary to pass unstored river water into supply without filtration, either because there exists no means for con-

veying stored water to the works or because the conduits which carry it may have been broken.

As previously stated, facilities for chlorinating both raw river water and stored water before it reaches the works have been provided, and it has, in the past, been the practice of the Director of Water Examination to approve the passage of chlorinated raw river water on to the filters as an alternative to stored water, either when stored water conduits have been fractured, or because of urgent necessity to conserve coal supplied by avoiding pumping river water up to the storage reservoirs. Considerable experience of the favorable effect of chlorination upon raw Thames water has been gained.

It should be understood also that unfiltered water would not pass into supply undiluted. It would be passed to the filters, and as much filtered water as could be drawn through the plant would reach the pumps, the deficiency only being made up by unfiltered water. The unfiltered water would be chlorinated at the intake and the mixture of filtered water, from which the chlorine would have been removed during filtration, and of unfiltered water, from which the pre-chlorination dose would not have been removed, would be re-chlorinated before reaching the pumps. There would thus be two chlorinating points so that, should one point be damaged, the water would not be entirely untreated, although treatment by chlorine alone might be considered inadequate.

There is, however, a possibility that raw river water may contain particulate fecal matter, derived either from storm water overflows or from fractured sewers draining directly to a river. For this reason, the Metropolitan Water Board is of the opinion that in no circumstances should unstored raw river water be passed into supply unless the public is warned that it should be boiled. When raw river water has been used in the past to conserve coal, it has been the practice of the Director of Water Examination to advise a change-over to stored water should flood conditions appear to be imminent.

Stored water is in a somewhat different category, because it is probable that particulate fecal matter would settle out during the passage of the water through a reservoir. It may be considered that the risk incurred by passing chlorinated, but unfiltered, stored water into supply is negligible.

### Use of Primary Filtered Water

Mechanical primary filters are normally used in conjunction with secondary slow sand filters. They remove all suspended matter except particles which are almost microscopical. The water supplied by them, although not always clear, is easily disinfected by chlorine. The water is

pre-chlorinated before passing to the primary filters where the chlorine is removed. In the past, there have been occasions when the supply from works provided with primary filters has been insufficient to meet urgent demands. On such occasions the Director of Water Examination has not hesitated to recommend that the primary filtered water be passed directly to the pumps, where it mixes with water which has passed through slow sand filters and is re-chlorinated before passing into supply, a procedure which is unorthodox.

## Pollution in Mains and Service Reservoirs

The Metropolitan Water Board is of the opinion that pollution of mains by sewage, resulting from the simultaneous fracture of mains and sewers or drains, constitutes the gravest danger which water undertakers have as yet been called upon to face. The methods which have been adopted against this danger are set forth in some detail in an article by Lt. Col. E. F. W. Mackenzie, Director of Water Examination (abstracted Jour. A.W.W.A., **33:** 793 (1941). The methods there described have, since the publication of the paper, continued to give uniformly good results, but the following points, are worth consideration.

When a main has been repaired and charged with heavily chlorinated water, the correct procedure would undoubtedly be to empty the main, to recharge it and to await the result of bacteriological analysis of the water before putting the main back into supply. This procedure is adopted in as many cases as possible when damage is not widespread. It entails keeping the main out of supply for perhaps 48 hr. longer than would be necessary if bacteriological analysis, and possibly also draining and re-charging, were omitted. If a large number of mains are fractured during one night's bombardment, it will be appreciated that grave interference with the water supply would be caused by rigid adherence to this rule and mains which were urgently required for fire fighting might unnecessarily be held out of supply. Moreover, the interruption of telephone services makes it impossible to arrange meetings between sample collectors and turncocks which are necessary to enable samples to be drawn.

During times of comparative quiet, as many mains as possible are sampled before being put back into supply, and are kept out of supply until the results are known. At other times, when there is evidence that gross contamination by sewage may have taken place, the main is sampled and kept out of supply until the results are known. Other mains are allowed to go back into supply after chlorination, emptying and re-charging, without sampling, if they are urgently required. When chlorination of a main is completed shortly before dark, and it is not, therefore, possible to empty and recharge it before blackout, the main is held charged all night and

orders are given that it may be put back into supply, although charged with heavily chlorinated water, if urgently required for fire fighting.

The sterilization of the large mains is supervised by responsible chlorination supervisors. The number of small mains fractured has been so large that sterilization of these must of necessity be left to more subordinate officers and the elaborate methods used for large mains cannot be applied to small ones.

Since the first aerial attacks upon London, over 700 samples have been drawn from repaired mains after sterilization and from three only has it been possible to isolate *Esch. coli* after the main has gone back into supply. The probable numbers of *Esch. coli* present in these three samples were 2, 2 and 1 per 100 ml.

In addition to the above 700 samples, 500 have been drawn at random throughout the area of supply, particularly from districts which had recently been subjected to intensive bombardment. All these have been negative to *Exch. coli*.

Thus, only three of over 1,200 samples examined failed to conform to the highest bacteriological standard, and in one of these only did the ascertained content of *Esch. coli* exceed 2 per 100 ml. of water.

Despite these highly satisfactory results, certain situations might be created which would cause the Director of Water Examination anxiety, for instance:

A number of service reservoirs are adjacent to drains or sewers and might become contaminated by sewage. The water from these reservoirs goes into supply by gravity and it is possible that, despite orders that a damaged reservoir should normally be shut in as soon as possible, some contaminated water might go into supply before the valves could be closed. It is possible also that it might not be justifiable to shut in a reservoir were it supplying water for fire fighting.

A similar situation, but one affecting a more restricted area, arises when a main and a sewer on a gradient are fractured together and when, after the closure of valves, a sufficient head to supply premises at a lower level may be maintained by the flow of sewage from the crater into the main. The danger of this has, to a great extent, been countered by instructions to turncocks to the effect that, when such a situation arises, the valve by which the lower end of the main is shut in shall be left slightly open. This maintains an upward flow in the main, the water pouring out at the site of the crater and running to waste. Any risk of sewage matter passing downwards into the isolated portion of the main until this can be emptied is thus minimized.

If for any reason the precautions above are thought to be inadequate, instructions have been made for notices to be issued immediately advising the public to boil their water.

**Metropolitan Water Board**

## NOTICE

The water supplied to your premises may be impure. Until further notice all water required for drinking or use in the kitchen should be purified by boiling or other means officially recommended. (See back)

R. P. MORGAN,

*Clerk of the Board*

NEW RIVER HEAD,
ROSEBERY AVENUE,
LONDON, E.C.1.

If you are unable to boil your water you can make it safe to drink if you add 10 drops of chlorinated soda solution to each pint of water, stir and allow to stand for not less than five minutes. If the taste of chlorine is objected to, it may be removed by adding one or two small crystals of photographic "hypo" after the chlorinated water has stood for five minutes.

NOTE — Chlorinated soda and "hypo" can be obtained from any chemist.

FIG. 1. Face and Reverse of Notice of Unsafe Water Supply; printed in red

## Issue of Notices Informing the Public That the Water Is Unsafe to Drink Unless Sterilized

Two notices have been prepared for informing the public. The first (Fig. 1) informs them that the water is unsafe to drink and the second (Fig. 2), that the purity of the supply has been restored.

These notices have been issued to local authorities for distribution by the A.R.P. Wardens' Organization. The board will order their distribution to householders concerned immediately it is known or suspected that the water supply to any district has become impure.

**Metropolitan Water Board**

**NOTICE**

**The water supplied to your premises is now pure and may be used for drinking, or other domestic purpose without any further treatment.**

**R. P. MORGAN,**
*Clerk of the Board*

**NEW RIVER HEAD,**
**ROSEBERY AVENUE,**
**LONDON, E.C.1.**

FIG. 2. Notice of Restoration of Safe Water Supply; printed in green

An additional notice informing the public how water may be sterilized by individuals has also been prepared, and has been distributed to consumers (see Appendix A, p. 1323). This notice has now been officially adopted by the British Water Works Association for issue throughout the country. The substance of the notice was broadcast by the Director of Water Examination on August 13, 1940.

### Other Precautionary Measures

The top water level in certain large reservoirs has been lowered as an emergency measure in order to reduce the risk of flooding and consequent damage to adjacent life and property.

A patrol system has been organized so that, in the event that bombs fall on the reservoir, early notification can be received by the engineers responsible for the operation of the appropriate works.

Damage to weirs may impede the abstraction of water from rivers. With a view to minimizing this danger the Metropolitan Water Board has authorized the purchase of shallow-draft barges fitted with pumping apparatus so that an adequate supply to the pumps may be maintained.

Extensive damage to filters may allow unfiltered water to gain access to filtered water. To provide against this contingency, steps have been taken to chlorinate the water prior to filtration, and pre-chlorination apparatus has been provided at a number of intakes together with any necessary booster pumps and portable chlorinators.

Bypass valves are being inserted at certain filtration stations so that, as the occasion may require, primary filtered water can be passed direct to the pumps; or, if necessary, raw water may be so passed.

The Metropolitan Water Board has taken steps to provide a large quantity of portable plant for use in the event of a major disaster to existing installations.

Careful consideration has been given to the location of stocks of plant and materials of all kinds to ensure that while the risk of damage due to concentration is reduced to a minimum, such plant and materials shall be quickly available in emergency.

The various water authorities have, since the onset of the war, maintained substantial reserve stocks of water distribution pipe. These reserves have contributed very materially to their ability to restore service after breaks in the mains occurred. It will be remembered that while the London Metropolitan Water Board exercises administrative jurisdiction over water supply in that area, water is secured, purified, pumped and distributed by more than ten water companies, each serving a portion of the metropolitan area and each separate system inter-connected with the adjacent ones. This feature of London's water supply was of great value during the period when air raids were severe.

Of the almost 8,250 miles of water distributing pipe in the area, 61.4 per cent is in 3- and 4-in. sizes, 19.5 per cent in 5- and 8-in. sizes, and 8.4 per cent in 9-, 10- and 12-in. sizes. The balance, from 14 to 54 in. in size makes up 11.1 per cent of the total. The reserve stock of cast-iron pipe totaled 1.15 per cent of the total length of mains. To that reserve was added

0.03 per cent of the total installed pipe in the form of steel. The greatest reserves were in 6- and 8-in. pipe, where the stocks were 2.5 and 2.9 per cent, respectively, of the installed footage in such diameters.

## 3. Repair of Air Raid Damage to Mains

Experience has shown that during any raid lasting even two or three hours a number of mains above 24 in. in diameter are usually broken. If the raid is of longer duration, the number of fractures tends to be increased in proportion, while if it is shorter the smaller mains, which are of course more numerous, do not escape. Therefore, in a large city such as London, damage to the distribution system is likely to be experienced even during light raids.

The limited experience which the Metropolitan Water Board has had with steel mains shows that they are not fractured over as long a length as cast-iron pipes and, owing to the ease with which they can be cut by an acetylene flame, are easier to repair. On the other hand, because of their relative thinness, these mains are more easily deformed than cast-iron pipes.

### Air Raid Damage to Mains

The use of cross (inter-system) connections has been of inestimable value. One of the most effective preparations against air raid damage is to insert such connections wherever possible even to the extent of laying short lengths of main to connect to the trunk mains. The connections should also be well provided with valves, as it has been necessary in a number of instances even to reverse the flow.

The repair of broken mains in craters presents unusual features. Usually a crater is full of debris and, if the road surface is concrete, large slabs of concrete will be found half buried in mud and sticking up at all angles. In addition, large pieces of pipe will be embedded in the ground and, owing to the general disturbance of the road surface, the timbering of the trench and provision for the support of a gantry present difficulties. It has been found that the use of six-ton portable cranes with long (say 24-ft.) jibs has been invaluable. An ample supply of compressors and road-breaking tools is also necessary.

In dealing with cast-iron pipes a thorough inspection of at least ten or a dozen pipes on either side of the crater should be made, as the explosion frequently splits pipes several feet from the crater. Joints adjacent to the crater may also be disturbed by the force of the explosion.

In built-up parts of London, mains up to 12 and 15 in. in diameter are almost invariably supplied from both ends. When such are fractured in craters, the supply has been maintained by breaking down and capping up such mains until the filling in or repair of sewers in the crater permits the

mains to be relaid. A large stock of caps of various sizes is therefore of great advantage.

## Pollution and Sterilization of Mains

Too great emphasis cannot be placed on the necessity of sterilizing mains after these have been damaged by bombing. Frequently a sewer is also broken and, either immediately after the explosion or during the course of the repairs, sewage-polluted water, and indeed sometimes crude sewage, finds its way into the water mains. For sterilizing mains of 12-in. and over in diameter a corporation cock is inserted and a portable chlorinator used to effect sterilization with chlorine gas.

Every effort has to be made to shut off water mains quickly where the fracture may cause flooding to gas mains. The organization of the turncock service, the protection of the men so engaged and the means of communication, especially when the telephone system has broken down, need careful planning to ensure that burst mains are shut down as soon as possible.

Sometimes the water mains in a crater cannot be repaired owing to damage to sewers at lower levels which necessitates keeping the crater open. Under these conditions it may be necessary to sling the main across the crater on a built up girder or to lay a bypass around the crater. The Metropolitan Water Board has purchased some built up girders, but so far has had no experience in their use, although it has on occasions constructed bypasses of welded steel pipe. Standard bypasses with tees and flanged pipes have been designed.

## Organization of the Turncock Service

While the distribution staff is under ultimate control from the Metropolitan Water Board's central offices, for purposes of administration the whole area is divided into 20 subdistricts, each of which is controlled by a district engineer. Each district is further subdivided into foremen's areas which, in turn, consist of a number of turncocks' walks. Each turncock is provided with an assistant and, in the light of experience, steps are being taken to augment this section of the district staff.

Arrangements were made prior to the war for the local A.R.P. controls to report damage to the turncocks, who would be standing by their telephones during air raids and who would then proceed to the actual site of the damage and shut down the mains.

To facilitate the selection of the turncock to whom a message referring to a particular locality should be transmitted, maps of each borough were prepared, showing the various turncocks' areas. These were distributed to the A.R.P. controls, together with key sheets of turncocks' addresses.

The great proportion of "incidents" messages have been correctly communicated to the turncocks and the damage to the board's mains has received immediate attention.

## Messenger Service

Because of the difficulties experienced in maintaining telephone communication, a messenger service operating from the district superintendent's offices has been organized, necessitating the employment of about 130 men. This has proved of the greatest utility.

Before the war, the Metropolitan Water Board purchased 350 bicycles for use in air raids. These are used continuously by messengers, foremen and others and the work could not have been carried out successfully without them.

Each turncock always carries with him a small key and bar with which valves on mains below 12-in in diameter can be opened or closed. For valves above this diameter heavier equipment is necessary, weighing in all about one cwt. (112 lb.), and two to six men may be required for their operation.

Arrangements are made to keep large keys and bars in the vicinity of some of the valves, but it is not possible to effect this for every valve, so the tools must frequently be carried some distance.

Shutting down a large main nearly always necessitates closing a minimum of two valves, which may be a considerable distance apart. In addition, most of the trunk mains and all the secondary mains have branches, especially in the inner portion of the metropolitan area, and these must also be closed before the water escaping into the crater is completely shut off. Further, the turncock, after he has ascertained whether the fracture has occurred to one or a number of a group of mains, has to make the selection—in the darkness and frequently under adverse conditions—of the correct valves from a number of boxes often covered with debris, water or mud.

The closing of large valves is not a rapid operation. A 24-in. valve requires a minimum of 48 turns, a 36-in. valve 72, while in certain instances where geared valves are employed the number is much greater. The final closing of the valve must be performed very slowly as the sudden stoppage of a large volume of water sets up a "water hammer" in the pipe which may result in a further burst. The total time to close each valve may take 30 to 40 min.

As has been the case with other public services, difficulties and "bottlenecks," hitherto unforeseen, have become apparent during the progress of repair work. Every endeavor is continually being made to improve the methods of coping with the emergency, including the provision of additional motor transport for personnel and supplies, and of an increased staff

for dealing with the unexpected extent of the damage inflicted by the raiders.

## 4. Water Distribution by Tank Wagon

The principal effect of enemy bombing on the London water system up to the present time has been to cause damage to mains. This may be divided into two categories: damage to small distribution mains and damage to large trunk mains. The first has only a local effect and in many cases the consumers can obtain a supply from a fire hydrant fixed to an adjacent main. The second has a much wider effect; and, if there is no alternative supply, a single bomb may render large areas wholly without water. Inter-connection between different trunk mains can offset to a large extent the effect of any single breakage, but the cumulative effect of fractured mains, and possible heavy demands for fire fighting, can reduce the pressure in the mains to zero or cut off the supply entirely.

If the supply of water is entirely cut off, arrangements have been made for distributing a small emergency supply by tanks carried on lorries. The size of these tanks is governed to some extent by the size of lorries available for carrying them and the loading facilities available at the places where the tanks are stored. 510 tanks have been purchased by London's Metropolitan Water Board and each tank holds 500 gal. or 2.24 cu.m. They are 1.83 m. long, 1.22 m. wide and 1 m. deep. The tanks are provided with two baffle plates, have a filling hole 23 cm. in diameter, covered by a hinged lid, and each tank has three outlets in the end, 2.54 cm. in diameter, fitted with a short length of hose pipe. The tank plates are 2.3 mm. thick and the whole of the tanks are galvanized.

In addition to these tanks, arrangements have been made to use a number of tank wagons, normally used for flushing streets or for conveying various other liquids such as milk. The capacity of these is between 500 and 2,500 gal. and slight modifications to the outlet pipes are necessary in some cases.

In general the 500-gal. tanks are intended for supply to private consumers and the larger tank wagons for supplying hospitals and other large organizations.

### Number of Vehicles Required

The number of vehicles required obviously depends upon a number of factors, among which are the amount of supply cut off, the size of the tanks, the length of haul from the place where water is obtainable, the supply allowed per head and any difficulties affecting transport. As a very approximate figure, it may be assumed that one tank of 500–600-gal. capacity, carried on a motor lorry with a haul of not more than 4 mi., will

supply between 1,500 and 2,000 people with about ¾ gpd. per head. Very large tanks do not possess any considerable advantages over medium size tanks for street distribution, unless the water has to be transported for long distances.

The tanks are stored at twenty different places throughout the area served, to avoid extensive damage through concentration in large numbers. The storage places are chosen on a geographical basis but generally are kept outside the central area where damage is most likely to occur.

One of the most difficult operations is the assembly of the fleet and getting the tanks into use, owing to the immense amount of additional work thrown upon the Distribution Section, the probable lack of telephone facilities and the speed with which the operation must be conducted. The time factor is affected greatly by the kind of damage done and the reservoir capacity available.

The 500-gal. tanks are carried on hired lorries which, until required, are engaged in other duties. The lorries belong to a large number of firms situated in all parts of London and because of telephone difficulties the collection of the lorries has been decentralized and is now undertaken by twenty local officers, each of which is responsible for issuing instructions to the lorry owners in his own neighborhood.

The general control of the arrangements is centralized. The officer in charge receives information from the control room of the need for tank wagons and issues instructions to the local officers to notify the lorry owners concerned, who will then have labor ready for loading the tanks and instructions as to where the lorries are to proceed for filling when loaded. The same arrangements for calling up apply to other tank vehicles except that they proceed direct either to a filling or a sterilizing station.

## Sterilization of Tanks

All the tanks which normally carry only drinking water are sterilized with chlorine powder before being brought into use. Sufficient chlorine powder is placed in the empty tank to give a strength of one part of chlorine to 120,000 parts of water and a contact time of 15 min. is allowed before the water is emptied out through all the delivery pipes.

Tanks which are normally used for carrying other than drinking water are steamed before use. Certain works have been selected for this purpose and steam piping is fixed ready. A pipe, or hose, is placed in the top of the tank and loosely packed with any convenient material and the exhaust steam, together with the condensate, escapes through the delivery pipes. After steaming, the tanks are chlorinated. The time required for steaming varies considerably, according to the condition of the tank and the liquid previously carried. Tanks used for light oils usually require from two to eight hours, occasionally much longer.

## Filling Arrangements

The board has a large number of small works situated in all parts of London and most of them have been selected for filling the tankers, as it is considered advisable to have tankers filled at specified places rather than at street hydrants, even if water can be obtained there. Unless the tank wagons keep in touch with the filling station the difficulties of organization become very great. The filling stations are so situated that no important area is more than 4 mi. from a filling station.

In addition to the above, a large number of private wells have been inspected and scheduled for filling tanks, should the board's filling stations be rendered unusable for any reason. It is hoped eventually to have about 200 private wells. The capacity varies considerably, but averages from 2,000 to 8,000 gal. per hr. All the water from private wells is chlorinated at the rate of 1 ppm. before distribution to the public.

The filling arrangements are under a central authority, since any filling station may have to be used to supply other districts. The officer in charge of each filling station is responsible for sterilizing the tanks, filling them, despatching them to the required district and is in charge of the personnel based on that station.

## Distribution

For ordinary purposes all distribution work is carried out by twenty district engineers, each in charge of a certain area. The distribution of water by tank wagon is based on the same organization and each district engineer is responsible for receiving and distributing the number of tankers allotted to him by the filling stations. The vehicles normally proceed from the filling station to a predetermined spot where they are met by guides provided by the district engineer and escorted to the areas needing water. Here they traverse the streets, distributing water as required, returning when empty to the filling station. It is found that vehicles average about two and a half trips per day.

Hospitals and similar large consumers are given priority. They are previously informed to whom they should apply when water is required and large tank wagons are sent direct from the filling station. It is important that large consumers should make prior arrangements for receiving water brought in by tank wagon. Difficulty has been experienced on occasions because no tanks are available at ground level and there are no means of pumping the water to high level tanks. This applies especially to factories.

Attempts have been made to distribute both "drinking water" and "non-drinking water," the latter being ordinary pure water distributed in uncleansed oil tanks and intended for sanitary purposes. It was, however,

found difficult to dispose of non-drinking water, the principal reason being that most private consumers have not sufficient vessels in which to store two kinds of water.

All the stores necessary for operating the scheme are already distributed to the various filling stations and are regularly inspected to see that they are in good condition. They include hose pipes, standposts, valve keys, chlorine powder, labels, paste, maps and instructions.

### Communications

Telephone communications are liable to interruption and all messages may have to be transmitted by hand. For this reason each person participating in the scheme should know exactly what to do before the emergency arises and so far as possible, arrangements should be decentralized. It is necessary to maintain central control over the general direction of the scheme, but it is possible to decentralize some of the work and transmit the instructions for putting it into operation by code messages.

The utmost effort must be made to induce all consumers to reduce consumption to the greatest possible extent wherever a serious shortage occurs. Economy in an area not itself affected will probably release more water for the affected area. Consumers with a storage cistern can exist for a considerable time without further supplies entering their premises, provided they realize in good time what is happening and practice rigid economy immediately.

Loud-speaker vans to tour the affected areas have been found very useful for conveying information to the general public and issuing warnings as to possible pollution.

## 5. Utilization of Private Wells and General Organization of Water Authorities

The possibility of such serious damage being sustained in London that normal sources of water supply may not be entirely available has been envisaged and a scheme has been formulated whereby use may be made of privately owned wells for the purpose of augmenting existing sources. The proposals include use of tank wagons for the distribution to consumers of water so abstracted.

The suitability of a well for inclusion in the scheme is dependent on several factors. Primarily, it is vital that the purity of the water should be of a standard not liable to affect public health and it is intended that all water drawn from private wells should be chlorinated as it is delivered into the tank vehicles. The fact that this will be done under emergency conditions must be taken into account in determining the minimum standard of purity to be adopted.

In addition, convenient arrangements must be available for filling tank vehicles. At some premises, the well installations are remote from positions in which tank vehicles could be filled and at others expensive structural alterations would be necessary before the water could conveniently be drawn. Samples of water have therefore been taken and tested only from wells regarding which the preliminary engineering report has been satisfactory.

As soon as these analyses have become known, essential particulars of all wells classed as "satisfactory" have been extracted and scheduled, distinction being drawn between those where suitable filling points, such as hydrants, are available and those where it is necessary to fix hydrants to enable water to be delivered into tankers.

Of the wells listed as satisfactory, suitable filling points have been found to exist in many cases. These usually consist of hydrants fixed either privately for fire purposes or as emergency connections by the local fire brigade. In cases where such points are not available, hydrants have been fixed.

Where it is necessary for hydrants to be specially fixed, owners have been asked to undertake the necessary work at the board's cost. While every effort is made to convince owners of the urgent necessity for completing the scheme as soon as possible, allowance has to be made for firms who cannot shut down their plant to effect the alterations except at weekends or after appropriate notice. Where owners cannot supply either labor or materials, the board carries out the work or supplies materials. In all cases it is intended to supply to each installation lengths of hose to be retained exclusively for the board's use. At some premises there already exist private hose reels which could be used.

In regard to storage, the inspections have revealed that many premises are provided with large storage tanks but that these are often open to the air with a consequent risk of pollution. Such pollution does, in fact, occur as is clear from the analyses of several of the samples tested. Furthermore, "process" water is often returned to a storage tank so rendering its contents unsuitable for drinking purposes. A situation might arise in which wells were out of action and the volumes of stored water available could not be distributed by reason of the danger to public health. The problem of maintaining open tanks in a fit condition for drinking is difficult to solve.

The utility of a scheme for making use of private wells in emergency depends on many factors which should be borne in mind when assessing the extent to which London might be supplied with water for drinking purposes in this manner:

*First*, the wells are not uniformly distributed throughout the Metropolitan Water Board's area or those sections of it most likely to be affected

by major damage to plant or mains. For some closely built up areas there is no approved well within several miles.

*Second*, the quantity of water which can be distributed is by no means equal to be capacity of the plant. It depends on the number and position of filling points, the facilities for accommodating tank vehicles while being filled, the number of tank vehicles mobilized in the locality at a time of emergency, the time taken to fill, the distance which the vehicles must travel in distributing the water and the staff available.

*Third*, most private well plants are dependent upon the public electricity supply for their operation. If this fails, the well is virtually useless.

## War Emergency Water Committee

A committee consisting of representatives of water undertakings within the London Civil Defense area has been appointed. The function of this committee is to consider and advise on matters of mutual interest with a view to the maintenance of an efficient water supply in the areas of the authorities represented on the committee and to render mutual help in times of emergency.

One memorandum (Appendix B, p. 1325) issued by the committee, which has been widely circulated, deals with the arrangements made for the distribution of water during an emergency.

The board's area is surrounded by various water authorities serving consumers within a comparatively small radius. It has been considered desirable that means be adopted whereby water can be passed from one authority to another in an emergency, and to this end an elaborate system of inter-communication has been evolved. By this means it is anticipated that large quantities of water may be made available in an area suffering from air raid damage, such water being supplied if necessary from a source remote from the affected area. Mains of different sizes are being laid for this purpose, together with any necessary connections.

## Liaison With Other Authorities

The day-to-day repair of mains consequent upon damage requires contact to be maintained with all affected parties including gas and electricity authorities in order that any unavoidable delay may be reduced to a minimum. It is of the utmost importance that priority shall be given to the repair of water mains and it is therefore essential for the district staff to be fully appraised of the progress of work intimately connected therewith, such as clearance of craters, debris, etc.

The Metropolitan Water Board keeps in close touch with the British Ministry of Health Regional Headquarters, with the Headquarters of the London Civil Defense Region and with local authorities. By this means

swift action can be taken in respect of urgent and important matters, including the allocation of labor and materials for the board's work.

### Conservation of Supply

Since the outbreak of war it has been necessary on more than one occasion to issue an appeal to the water consumers of London to exercise the utmost economy in the use of water. Such appeals have stressed the fact that all London's water has to be pumped, involving an equivalent use per annum of 203,210 metric tons of coal. Moreover, it has been pointed out to consumers that economy in consumption means reduced demands, that reduced demands mean reduced fuel and that reduced fuel reduces the bills that the board has to meet, resulting in a reduction of the financial demands made on consumers by the board.

There has been a ready response by consumers to the appeals made by the board in this connection.

### Control and Co-ordination

The ultimate control of the board's undertaking is vested in the Chairman of the Board, assisted by committees selected for different purposes. He is advised by chief officers who are technical experts.

The prompt execution of measures for the maintenance and safety of the supply makes the most exacting demands and it is therefore evident that the responsibility carried in such circumstances by the Chairman is a heavy one.

The Chief Engineer is kept advised constantly both day and night of all damage sustained and it is his responsibility to initiate such works of repair as may be required. A central control room at the head offices of the board is continuously manned and acts as a means of liaison between outside authorities and the board, as well as a report center for serious damage.

The Director of Water Examination is responsible for the maintenance of the purity of the supply and collaborates closely with the engineering staff.

## 6. Sterilization of Repaired Water Mains

The chlorination of large mains is carried out by chlorination supervisors under the direction of the Director of Water Examination, who has a scientific assistant for co-ordination of the work in the various districts, for the allotment and control of chlorinators and towing vehicles and for general supervision. The area supplied has been divided into several districts to each of which one chlorination supervisor has been allotted, who has at his disposal two mobile chlorinators and one towing vehicle. Each mobile chlorinator is staffed by one chlorination attendant.

The chlorination supervisor is thus enabled, if necessary, to take a chlorinator with its attendant to a main, to make the necessary arrangements for chlorination and then to leave it in the care of the attendant, while he is free to collect a second chlorinator and start it on a second main. Having done this, he can return in the towing vehicle to the first main to perform the necessary tests and collect the chlorinator when the operation has been completed. Should the work in one district be heavy, relief can be provided either from another district or by bringing in reserve vehicles under the instructions of the Director.

Efficiency and smooth working are secured by the closest liaison between the engineering and chlorination staffs in each district.

Complete records are maintained in the Director's office by means of a card index. On receipt of notification that a main has been fractured, a card is made out and any relevant information is subsequently recorded thereon. Each chlorination supervisor keeps in touch with the work in his district and records progress on a report sheet. When chlorination has been completed the report sheet is forwarded to the Director's office, where it is attached to the appropriate card. If samples have been drawn, the results of analysis are recorded and the card and report sheet are filed for future reference.

## Procedure

The primary objective in endeavoring to achieve effective sterilization is to ensure that heavily chlorinated water shall be distributed throughout the whole section of the fractured main which has been isolated. The procedure has been standardized, as far as it is practicable to do so, to avoid the necessity for consultations at a time when the staff is already fully occupied. In the case of large mains, and particularly of trunk mains, when it may be necessary to isolate considerable lengths, or when heavy contamination with sewage is known to have taken place, some departure from any standardized procedure is often permissible and desirable. In such cases there is time between the fracture and the completion of the repair for a conference to be arranged between the distribution and the water examination staffs. The procedure recommended, briefly, is as follows:

### *Small Mains*

Small mains may be sterilized by means of stabilized bleach. The quantity introduced should be sufficient to give a concentration of 10 ppm. in the estimated capacity of the main. It is advisable to prepare a table which shows at a glance the quantity of powder necessary for different lengths of mains of all sizes.

Before the powder is introduced every available means should be used to empty the isolated section of the main. The mere introduction of the

powder at the site of the fracture has proved to be inadequate. In the case of some small mains there may be a hydrant in a suitable position close to the charging valve, and the powder may be introduced through this. In other cases, however, where there is no such hydrant, it will probably be necessary to shut down an adjacent length of main on the charging side of the damaged section. If the powder is introduced through a hydrant on this section and the damaged section is then charged up through the undamaged section, the chlorine may, unless the main runs uphill, pass the polluted section before the main is fully charged, thus sterilizing the invert only. When the main is fully charged, the wedge of heavily chlorinated water should, by manipulation of valves and hydrants, be forced back through the repair.

When the powder is introduced into a main through a hydrant, the main should be emptied as far as possible and the powder flushed into the main by means of a few bucketfuls of water.

In view of the high dose of chlorine administered, it is advisable to wash out the chlorinated water and, if this is done through a valve or hydrant at the end through which the main was charged, this procedure may be combined with that of forcing back the wedge of chlorine through the repair.

*Large Mains*

Every practicable step should be taken to empty every part of the isolated section of the fractured main.

It is usually of the utmost importance that the chlorine shall be introduced at the point at which the main is to be recharged after repair. It is necessary, therefore, to expose the main for insertion of a corporation cock as near to the charging valve as is practicable. In cases where a main is to be recharged through a cross-connection, the cock may, if found convenient, be inserted in the cross-connection.

If the above operations, i.e., draining the main and inserting the corporation cock, are carried out concurrently with the repair of the fracture, they do not cause any delay.

A water supply capable of giving a sufficient flow to operate the chlorinator during the period of charging should be made available, either from an adjacent main or, if necessary, from a tank truck.

The chlorine dosage should be adjusted to deliver sufficient chlorine to give 10 ppm. in the volume of the empty section of the main in the estimated time of charging. This estimate is liable to considerable error, and it is a wise precaution to calculate on the shortest probable time, so to overdose rather than underdose.

Charging the main should not be commenced until the chlorination supervisor is satisfied that chlorination is proceeding.

When a main is being chlorinated, charging should continue and the water should be run to waste through the air valve, hydrant or emptying valve situated nearest to the opposite end from that at which it is being charged, until the presence of chlorine can be clearly demonstrated in the water discharging at that point, thus indicating that any dead water in the main has been discharged.

When it has been recognized that chlorine has been distributed throughout the whole isolated section of the main, the main should be allowed to stand fully charged for not less than 15 min.

Owing to the necessity for using high concentrations of chlorine to effect rapid sterilization, it is most undesirable that the chlorinated water be allowed to pass into supply. Unless very strong reasons exist for doing otherwise, the main should be emptied after it has stood for the specified time and should be recharged before it goes into supply. This will, at times, be impossible. In view of the grave nature of the risk involved, the avoidance of chlorinous tastes should not receive the consideration which it merits in normal times, unless this can be achieved without lessening the safety factor. When it is not possible to empty the main the dose should not therefore be reduced.

There is a widespread realization that a chlorinous taste spells safety so complaints have been few. Should serious tastes result from inability to empty sterilized mains, it is a simple matter for the consumer to add a small crystal of photographic "hypo" to the tea kettle or water jug. This, even if added in excess, is quite harmless and completely removes any taste of chlorine.

## Results

### *Small Mains*

Many small mains have now been treated by the method described, although only a comparatively small number have been sampled. This has resulted from the fact that, to ensure a representative sample, it is necessary for the sampler to be present when the pressure is restored and the main is put back into supply. Difficulty in rapid communication and the inability always to forecast even the approximate time at which a repair would be completed have made this impossible, except in a limited number of cases, without delay in putting the main back into supply. It is fully realized that the correct procedure would be to await the result of analysis before putting the main into service, but in prevailing conditions the delay inseparable from such a procedure could not be justified.

Of the samples drawn from small mains treated by the method described, 100 per cent have proved to be negative to *Esch. coli* in 100-ml. quantities.

Despite the good results, the method is recognized as a compromise between efficiency and expediency. It is, moreover, impossible for responsible officers to exercise control over the very large number of small mains which may require treatment. For this reason, the concentration of chlorine in the water passed into supply from the works has been raised in an endeavor to maintain as effective a residual as possible at a distance from the works, without giving offense to consumers who receive the supply more directly. The value of residual chlorine in the mains is a subject beyond the scope of this paper, but it may be advisable to state that the very small residual usually passed into the mains is totally inadequate to counteract, in the time available, the type of pollution which may result from the disruptive effects of a bomb. The bactericidal effect of a small residual in a limited time is very much less than is commonly believed, and this is particularly so when the lag in sterilization is prolonged by the use of ammonia.

The methods used in the treatment of small mains have of necessity been less complete than had been desired, and it is hoped that their manifest weaknesses will stimulate investigation which may lead to a better solution of this difficult problem. Nevertheless, the satisfactory results obtained from the admittedly inadequate number of samples which have been analyzed indicate that a considerable degree of success has been achieved.

*Large Mains*

With regard to large mains, it is appreciated that physical conditions may exist, which, in theory at least, may cause the methods advocated to be inadequate. In practice, however, they have, up to the present, been eminently successful. Whenever it has been practicable to do so, large mains have been sampled immediately they have been put back into supply. Of all such samples 100 per cent have been negative to *Esch. coli* in 100-ml. quantities.

A further check on the results of treatment of mains, both large and small, is to be found in the results from samples drawn at random throughout the area of supply, either from domestic taps or through sterilized hydrants from the mains. Since the onset of intensive bombardment, 68 such samples have been analyzed and in no case have *Esch. coli* been recovered from 100 ml. of the sample.

It is hoped that the description of the methods used may be of some assistance in areas where experience is still limited, but it should be emphasized that satisfactory results cannot be achieved by any ready-made formula. The efficiency of the chlorination process and the avoidance of delay must always depend upon the facilities provided, intelligent employment of them, constant vigilance and effort and the highest degree of co-operation between the engineering and the chlorination staffs.

It may, perhaps, be justifiable to quote one admittedly extreme case as illustrating the conditions in which the method described has been successful.

A bomb fell on the crest of a hill and made a crater in which were the broken ends of a 16-in. main and a sewer. The crater filled with a mixture of sewage and water. The main, which fell away downhill from each side of the crater, was isolated by valves about a quarter of a mile distant on one side and three-quarters of a mile on the other.

When the main was shut off it was found that the crater rapidly filled with sewage. This was kept down by pumping during the day, but at night pumping was not permitted and the trench filled with sewage, which poured into both ends of the main. When the repair was nearing completion, one leg of the main was emptied through an emptying valve and the other leg was drilled for a corporation cock immediately in front of the charging valve. This leg of the main emptied itself through the hole made. When the repair had been completed, chlorination was started and a good dose put in before the charging valve was opened. The administration of chlorine was continued until its presence could be demonstrated at the bottom of the opposite leg and the main was fully charged with chlorinated water.

As this was a case of pollution in extreme degree and the main was known to contain large quantities of particulate matter, the usually short contact time was extended to several hours. A sample drawn after the main went back into supply gave the following result: *Esch. coli* in 100 ml., *nil;* 24-hr. colony count at 37°C., 2 per ml.

It would not be right to conclude this article without reference to the loyalty and self-sacrifice of the chlorination and laboratory staffs who have worked for long hours throughout air raids, frequently during the night under aerial bombardment.

## Appendix A

### Text of Notice on How to Sterilize Water

The water supplied by the Metropolitan Water Board has, up to the present, been maintained at the high standard of purity associated with it in the past. Other cities which have been subjected to intensive aerial attack have, however, been less fortunate and their experience may at any time be repeated in London. *The advice given below is offered to enable you to know what to do should this occur.*

#### Emergency Supply of Drinking Water

A supply of pure drinking water, sufficient to tide over a short emergency of, say, two or three days, should be kept ready for use if the supply to

your premises is cut off by enemy action. The water is best stored in clean stoppered bottles kept in a cool dark place. It is not necessary to use this water for making tea as boiling will rid any water of disease germs.

### Pollution of the Supply

If the water supplied to your premises becomes impure you will be warned as soon as possible by means of notices delivered at your premises. You should then purify all water required for drinking or for use in the kitchen, or use only the reserve of water referred to above. When the purity of the supply has been restored you will receive a second notification.

### How to Purify Impure Water

(a) BOIL THE WATER, or

(b) CHLORINATE THE WATER.

If for any reason you cannot boil water, it can be made safe to drink by chlorination. Keep in your house a bottle of *chlorinated soda solution. Milton* or *Chlor-San* will do as well. Buy also a small packet of photographic *hypo.* These materials are cheap and can be obtained from all chemists.

*To purify the Water:*

(1) Add 10 drops of chlorinated soda solution to one pint of water (a tumbler holds about half a pint).

(2) Stir well and allow to stand for not less than five minutes.

The water will then be safe to drink, but will taste of chlorine. This is quite harmless and the taste can be removed by dissolving in the water one or two small crystals of hypo.

You may require to purify a larger quantity of water for use in the kitchen (e.g., washing fruits, salads and eating utensils) and this may be done in a clean bucket. The ordinary bucket holds about two gallons. For this quantity add two teaspoonfuls of chlorine solution, mix and allow to stand at least five minutes. If desired the chlorine taste may be removed as before by the addition of hypo.

### Remember the Following Points:

(a) Do not add the hypo until at least five minutes after you have stirred in the chlorine. It destroys the chlorine and will not purify the water.

(b) Treat each quantity of water separately. Do not chlorinate water to which hypo has been added.

(c) Do not use any disinfectant other than chlorine for purifying water unless you first obtain the advice of a qualified chemist.

**Note:** Should the only water available contain particles of solid matter it should be strained through a folded handkerchief or similar material before treatment.

### Contamination by Mustard Gas

Should the enemy use mustard gas it might be present in water as oily globules which *sink to the bottom.* If this is seen the water should not be used for any purpose and the A.R.P. Authorities should be informed.

### Shortage of Water

Do not drink water obtained from sources other than the mains or drinking water carts unless it has been boiled or chlorinated as described above.

Do not be alarmed if the water supplied to your premises has a taste of chlorine. This is an indication that the purity of the supply has been safeguarded. If the taste is objected to it may be removed by the addition of a crystal of hypo.

R. P. MORGAN
*Clerk of the Board*

NEW RIVER HEAD,
ROSEBERY AVENUE,
LONDON, E.C.1.
*April* 1941

## Appendix B

### Text of Memorandum of the Arrangements Made by the War Emergency Water Committee, London Civil Defense Region, for the Distribution of Water During an Emergency

The water works and mains may be so damaged as a result of enemy action that the normal supply of water cannot be maintained, and in some areas it may fail completely. Hot water systems which are properly designed are so arranged that there is no immediate danger of a boiler bursting if the water supply fails when a fire is burning, but in such an event it is advisable to put out the fire as soon as possible.

When damage to water mains is local, standpipes will be fixed and consumers will be expected to fetch water as required. To provide for possible failure of supply over large areas, a scheme has been prepared by the War Emergency Water Committee, London Civil Defense Region, for the distribution of water by means of tank wagons. The quantity of water which can be distributed by tank wagon is very small compared with normal supplies, and the utmost economy must be exercised. The tank wagon supply available for all purposes will probably not exceed one gallon per person per day. This amount represents about a half-bucket of water.

Within the area supplied by the Metropolitan Water Board, the district engineers will be responsible for the distribution of water in tank wagons.

Each morning they will collect information from their staff and estimate the number of tanks required. The tank wagons will be sent to predetermined points, where they will be met by guides. The guide will keep in touch with all tank wagons in his charge and arrange for the distribution of water, and will inform the public where water is available.

Similar arrangements will be made in the case of other water undertakings within the London Civil Defense Region; the engineers to the respective undertakings will be responsible for the local organization.

Hospitals, institutions and essential food suppliers will be given priority over all other consumers. Private consumers will be given preference over trade and meter supplies.

Factories must make certain that they are in a position to accept delivery of the water before tanks are sent.

The scheme will be operated by the water undertakings, but Local Authorities can, through the wardens' organization and in other ways, render material assistance not only to the water undertakings but also to the consumers, if they will take every opportunity to emphasize the need for strict economy in the use of water when a shortage occurs. This economy should be exercised generally and not merely in the areas where there is some interruption of the normal supply.

The tankers and lorries to be used for the emergency distribution are employed on their normal work until they are required for the distribution of water. Telephone communication may be difficult at such a time and some interval must necessarily elapse before the fleet of vehicles is marshaled and the scheme put into operation. It may, therefore, not be possible to commence the actual distribution of emergency water supplies immediately the interruption occurs, but it is expected that the arrangements will be working smoothly before the need becomes urgent. Many houses have storage cisterns and the water contained in them, if used sparingly, can be made to suffice for the essential needs of the average household for a much longer period than is popularly imagined.

Instructions have been given that all drivers and guides of tank wagons must keep strictly to the official orders issued to them by the water undertakings.

It is particularly requested that complaints received by local authorities from householders dealing with the failure of suppy should *not* be referred by telephone to the distribution staff of the water undertakings.

Should it be considered necessary, in exceptional circumstances, for any communications to be sent by the Local Authority to the water undertakings regarding emergency supplies in their area, it should be forwarded in respect of the Metropolital Water Board to the district engineer for the area. The names, addresses and telephone numbers of the district engineers and the particulars of the districts which they control have already

been notified to all A.R.P. controllers. In respect of other water undertakings, all communications should be sent to the engineer of the undertaking concerned.

### Information to the Public by Means of Loud-Speaker Vehicles

In the event of serious dislocation of the water supply, the Ministry of Information have arranged to broadcast a series of standard-type announcements, such as the following:

1. *Your water supply is cut off. Use the water in your cistern with great care. Water tank wagons will be sent around.*
2. *The water supply is restricted. Please use as little as possible and help one another.*
3. *The water in this district is impure. Until further notice it should not be used for drinking or in the kitchen unless boiled or sterilized.*

These arrangements will be brought into force at the request of the water undertaking concerned.

HENRY BERRY,
*Chairman*
R. P. MORGAN,
*Secretary*

NEW RIVER HEAD,
173 ROSEBERY AVENUE,
E.C.1
*4th June* 1941

# Effects of Air Attack Upon Utility and Other Structures

*By Walter D. Binger*

When I went on a trip to England in September 1941, I took with me some 200 questions covering all the different categories and phases of utility service and protection. These questions were prepared by the National Technological Civil Protection Committee, consisting of one representative of each of the important American engineering societies. Among others on the Committee are Mr. Jordan, representing the American Water Works Association and Mr. Wolman representing the American Public Health Association. So, I went to England not merely generally curious or searching for an impossible thing to find, but rather asking specific questions and ready to discuss them.

Before covering in detail the effects upon utility plants, it may be well to cover generally the several topics of civilian protection, such as blackouts and camouflage.

I have decided to take a chance, a very risky chance, and to define civilian protection. I define it as: "The maintenance, during and between bombing, of cities, towns, and the transport between them, in a condition as nearly normal as possible."

If that is startling to you, I think it is probably because, in spite of the fact that you are an engineering group, you are still thinking of civilian defense in terms of the protection of human beings and it certainly is not only, or even primarily, that. Of course, the human being is the most essential part of it because if the factory hands are all bombed then the important war factories will have to slow up, the same as if the factories were bombed. But the vitally important thing is to keep the war going on and civilian protection has become an integral part of the means of waging war.

They do not attack the civilians because they think it is fun. They attack them because they think it is one of the ways of putting the opposing country out of the war. The British do not subscribe to that view. They

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A presentation on June 23, 1942, at the Chicago Conference by Walter D. Binger, Chairman, National Technological Civil Protection Committee, and Engineer, Borough of Manhattan, Municipal Bldg., New York, N.Y.

think the Germans have wasted many of their bombs. They feel that if the Luftwaffe had put the share of bombing on the factories that they did in bombing civilians they would have had much more to show for it.

## Dimouts and Blackouts

I want to mention two operations of civilian defense in the United States that seem to be rather new, and which I did not find in England. When the war broke out England went into a complete, permanent and universal blackout. You could not see a single light at night from one side of England to the other. And that included the railroads. There are hoods like the old covered wagon built over all the locomotive fire boxes. As the firemen stoke the fires, they take a terrible beating of heat and fumes.

We have a different problem in this country. It is the instantaneous blackout while the dimout is our substitute for the permanent blackout. The dimout is very difficult to achieve, in a way far more so than the blackout for its criteria are relative instead of positive and absolute. When outside of Sandy Hook in a Coast Guard vessel on a black night when the dimout was being introduced it was quite shocking to find that buildings along the beach in Coney Island, themselves quite without illumination, stood out like sentinels against the ten or fifteen miles of sky glow or "loom" behind them. That has, of course, been remedied now. New York is already a much darkened city. The other difficulty of coastal and inland cities is the instantaneous blackout. We in New York have a modern lighting system and the lights go on a few minutes later every day as spring approaches and they light a few minutes earlier as autumn approaches. This control is maintained by astronomical switches. There is no way of turning those lights out at a single point without turning out all the power for elevators and pumps and other equipment. There are 38,000 switches to be turned by hand and about that number of wardens required to service them.

We are doing much in the way of flood lighting and guarding against saboteurs in the United States, but in England I did not see a single flood light. I was never able to find out that they had any fear of saboteurs at all. Yet everything is well guarded. The Home Guard is present with rifles in the big plants and sleeps there. I made it a point not to ask any questions that seemed to be even a little off my own line, but I had the impression they were not guarding those places against sabotage but against the possibility of invasion. London is thick with barbed wire. You cannot get near to any important buildings except at a certain entrance. Rolls of barbed wire, which would stop motorized vehicles, are kept up on the side of each principal street and could be quickly pulled across the driveway.

## Camouflage

Camouflage, a very active branch of civilian defense, is now being increasingly carried out in this country on the big industrial war plants. All belligerents are believers in it in spite of its known shortcomings. It is even possible, although much more difficult, to camouflage a plant such as a pumping station which can be identified in relation to a body of water. It is not hard to locate a plant near a body of water, but if it cannot be clearly seen the pilot may have to approach it twice before he can dump his bombs and he may never have the second chance.

It is possible to build models of plants and to examine them from viewing platforms, with various lights—moonlight and starlight and sunlight—until one gets a pretty good idea of which scheme of camouflage will work and which will not work, under varying conditions.

## Incidence of Bomb Hits

With respect to planning for water supply breaks and in setting up the control centers, some people think in terms of 100 breaks per 2,000 or 3,000 population. There does not seem to be any law for that at all. It depends upon what kind of bombing raid might be expected. For instance, in the famous incendiary raid on the City of London around St. Paul's they concentrated their entire raid in hundreds of thousands of incendiaries and many high explosives right in one relatively small borough and did frightful damage, but in general there has not been any such concentration. Looking at various raids, I do not believe there is any way of judging how much you would get. Surely the English raids on Germany are making the earlier ones on England seem light. It depends on what kind of bomb the plane is loaded with and what the pilot is specifically ordered to do. Even then you get very different effects. It has been estimated that only about 15 per cent of all the incendiaries that were dropped would actually light fires because many of them would fall in parks and paved streets and places where they could not light a fire.

You must bear in mind that all bombing is divided into two classes. It is either target bombing or it is area bombing. A very big and important structure, such as a huge municipal power house of the kind we have in all principal cities, is very likely to be a target in itself, and the bombardier will have instructions to aim for it. The object then is to force him into area bombing by all the tricks of the trade, namely, camouflage, blackout, and anchored balloons, and to use everything that will keep him at high elevation or make him hesitate the few seconds that he has available to aim through his sight. A bomber flying at 10,000 ft. has to dump his bombs three and a half miles away. He sees a structure at a very flat angle. He does not see it as you do when looking down from a passenger airplane.

By that time he is too late to bomb. Flying at from 300 to 400 mph. he has seconds to get set and dump.

## General Effects of Bomb Hits

If the bombs should ever fall here I can make a dogmatic statement to the effect that there are certain groups of men such as you who are going to have many headaches. Not that bombs are any respecters of persons. Everything within about 50 ft. of the perimeter of a large bomb crater will be fractured if it is in the ground. This, of course, is true of gas and steam as well as of water lines, and telephone, too, though that has been reinforced by short wave radio as far as communication within a city is concerned. But water is the essence of the entire fight for protection of the city for it is the vital substance to oppose to the very weapon the enemy is employing. That is why it is so terribly important to keep it flowing. As in the case of other public utilities, the distribution system, in this case the water main, is, of course, far more vulnerable than the production, or the manufacturing system. That is why they found in London that the many cross connections* available in modern pipes of the ancient water distribution system, the first part of which was laid out in Queen Elizabeth's time, made the city safer.

It is known that in one incident a main carrying 70 mgd. was fractured by bombing and within several hours they had water back in that district. The pipes wandered throughout the middle of a thickly built up district and required a great maintenance expenditure during peacetime. But because of the cross-connections they were invaluable on that day. The Chief Engineer of the London Water Board said that we ought never again to make a repair in this country when we had opportunity of making a connection between systems without doing so.

As for damage to treatment works, I could not get any information that any treatment works had ever been damaged. Some may have been, but if they were, I do not know it. Personally, I doubt it.

When bombing comes about, if it comes, you can expect to have the latest technic tried on you, which is a nice admixture of all the different kinds of bombs, that will do the most harm, together. In other words, if there is a great incendiary attack there will also be enough high explosive bombs to make the streets relatively impassable for fire engines and to break water mains; and there will also be the sprinkling of those inventions of the devil, the time-bombs.

* These are not cross-connections in the sense usually employed in the American water works field and in the JOURNAL. The reference here is to inter-system connections, that is connections between two supply systems.

The time-bombs, of the kind that the Germans use, have fuses set to go off anywhere from a half hour to 96 hr.; none any more than 96 hr. In order not to execute most of the men who have to dig out the time-bombs, it is the custom in England to rope off a zone where such a bomb has fallen and to wait. If it has not exploded in 96 hr. it will not explode. But you can see what the loss of manpower is in that kind of system. A 500-lb. high explosive bomb hitting the corner of a small factory would probably blow the corner off it and the men would be at work again in a few hours. But if a 500-lb. time-bomb dropped down beside the plant, they would have to evacuate everybody from the entire factory for 96 hr. The losses from time-bombs have been many times the equivalent of losses of the same number of the other type. Can you see what that means to water supply and water works, when all the roads around them have to be roped off? You cannot easily get near the place to repair the main that has been broken.

## Work Under Fire

The British have shown great courage. The chief engineer of the most bombed railroad told me that a time-bomb fell near the principal switching tower of a huge freight, or goods, station, as they call it, which had just taken a terrific bombing. There were many fires burning and it was very important to move out the trains. The signal man refused to evacuate; signalled out all the trains, emptied out the yard and only then got out of the tower. Seventeen minutes later the time-bomb went off, blew up the tower and everything around it. As near as I can tell that is about the way they are working.

They showed the same character in the repair of their water pipes. C. Frank Allen, a famous old professor of M.I.T., whom some of you may have known, used to say the way to judge an engineer was: first, character; second, judgment; and third, technical proficiency.

The British had to make an important decision right at the start—should they make temporary repairs to their water mains or permanent repairs? There was the temptation, as you can surmise, to make temporary repairs when every night the same shower of bombs would come down. But they decided that if they made temporary repairs they would have to dig up their whole city again when the bombing was over. When I was there in the late autum of last year, which was less than 90 days after the last great air raid, 96 per cent of all the water mains in London that had been bombed were permanently repaired and the streets repaired—96 per cent! A somewhat smaller percentage of the gas mains had been repaired.

Although many protective measures will be cited below, it does not mean that the time has yet come to expend large sums of money in making any

of these utilities ready for bombing. In the first place I think that is a decision we must ask of the military forces. They must tell us what zones must be protected. They have already said that zones within 300 mi. of the two oceans are vulnerable. I have no idea whether Chicago would be vulnerable. That is a military question.

### Damage and Protection of Pumping Stations

Now as to the important pumping stations. What can you do with them? I could not find out that any radical reconstruction had ever been made in England during the war—no reconstructions of factories or other plants on a radical basis. It is well known over there that in the aggregate splinters do the most widespread damage. In other words, the areas within zones of direct hits are relatively small but there is enormous and remote damage from splinters. Glass splinters, for example, have caused 10 per cent of all the casualties to people in Britain. Bomb splinters caused only 2 per cent. The rest have been caused by collapses and fire, blasts and other phenomena. Therefore, the English have gone very heavily in the direction of protection against splinters. They protect their machinery by blast walls and they protect their generators and fuel pumps by actual construction covering the entire machine.

The generators are protected by putting a couple of inches of cork over the metal and casing that in about 12 in. of concrete, fully molded into sections with superb workmanship. Ring bolts are buried in them so they can be lifted off by a crane.

Another great source of damage to machinery is the skylight. Besides constantly conflicting with the blackout, the skylight is deplorable because all glass is generally broken within 200 ft. of a high explosive bomb and very often within 600 ft. The skylight comes down and the glass gets into the machinery. They put heavy wire mesh under the skylight and lay thick felt on that netting which has a triple effect. In the first place it protects the machinery against the falling glass. In the second place, it makes the blackout effective, and third, it forms a roofing in case the skylight is blown out. All of those are essential.

In some American high pressure pumping stations for fire purposes, windows are now being bricked up. That is a simple and inexpensive thing to do and is a highly desirable precaution. By blocking up all the high windows, a great deal of safety work is accomplished for very small cost in a truly vital installation.

If you have a very small pumping station which is not a prime target in itself and cannot be easily seen, it is worth while examining it from a point of view that Dr. Wolman suggested and which I carried to London. He had a theory that so many bombs have been dropped on England that

everything that could happen had happened. Therefore, it was more desirable to study the situation from an actuarial point of view (the way a life insurance company would study it) than from a hypothetical point of view about what might happen.

I cannot cite to you the actual categories that I studied but it is a fact that I did inquire as to whether any of certain classes of small buildings which were not in themselves primary targets, which could be picked out by a bomber, had ever been hit. I found out that no building of this kind in England had ever been hit. But that is purely a matter of chance. If you had walked around England and made a chalk mark on an equivalent number of buildings, then by the law of chance they probably would not have been hit either, and that shows you the great possibility that your own small pumping plant will not be hit, providing of course that it is not a selected target.

### Damage to Dams

There is only limited information on dams. The published fact is that no dam has been seriously injured in England. The general belief is that it is extremely difficult to damage a heavy masonry dam by air bombing and that it would not in general pay. The National Technological Civil Protection Committee is at this time in discussion on that subject with the Army.

The Army has already published certain facts that seem to be very important. One statement made in an official Army publication is that a bomb which fell into the water near a granite wall blew a hole into the granite wall 50 feet in diameter without having hit the granite. It does not state the depth, and, of course, we know that the near miss in the water may do more damage, from the hydraulic hammer, than from actual hit. On the other hand the record of attacks on dams which have thus far been made have done no great damage. But bombs are constantly increasing in size and effectiveness.

I do not want to give you the impression that we have to learn everything from England and abroad. We ought to have enormous advantages in our country. It is acknowledged that the English did much because of pressure of time and circumstances which caused them to do things they knew were not the best. I think our repairs will be on an entirely different order of magnitude, because of our far greater use of machinery in construction. I think there is no doubt that, relatively, the modern American city with its far greater proportion of truly fireproof buildings would weather such a storm as the British had to meet.

# Water Supply Protection in Civilian Defense

***By Ralph E. Tarbett***

TO ATTEMPT to outline the problems that face you in planning and preparing for protection of water works against enemy action and for maintaining water service during such action is much too great a task for this short paper. I will, therefore, touch only on a few points that you should consider in your planning for this work.

Protection against sabotage is important. It should be borne in mind, however, that the extent of protection needed is in proportion to the value of the facility from the war effort standpoint. Water supplies that are essential or important from that standpoint constitute less than 10 per cent of the total number. The mutual aid system is an essential part of the protective program. Such a system was developed in Scotland at the beginning of the war and operated with excellent results during the air raids.

For the past two years the American Water Works Association has urged that water works' plans be made complete and accurate and that all control gates be definitely located and in operating condition. Lack of complete and accurate plans and records of underground structures has retarded restoration work in Great Britain. Have you followed the recommendations of your Association?

I will not go into details of the over-all plan for air raid protection, but that is a subject that each one of you should study carefully so far as it applies to your community or area. Ignorance of these plans and procedures will be no excuse if your particular activity fails to function properly when and if the emergency occurs.

The people in the cities of this country have become so accustomed to an adequate supply of good water available at the tap that they have a tendency to overlook its importance in the well-being, if not the very

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A paper presented on June 23, 1942, at the Chicago Conference by Ralph E. Tarbett, Sr. San. Engr., U.S. Public Health Service, and Chief San. Engr., U.S. Office of Civilian Defense, Washington, D.C.

existence, of the community. The maintenance of an adequate and safe supply of water is necessary for the continued existence of a city in normal times. How much more important it becomes then in times of stress and disaster! You and I know the trials, tribulations and the technical skills required in making water available at the taps of the consumers. The general public knows nothing of this. This lack of knowledge of the problems involved in procuring, treating, pumping and distributing water in normal times, let alone during a bombing, may account for the place accorded water supply in the earlier planning for civilian protection against air raids. Are you sure that maintenance of the public water supply is properly recognized in the protection program of your city? Or is it still considered simply from the standpoint of repair to mains and classed with road repair?

## Water Supply and the Protection Program

The first point I wish to impress upon you is that maintenance of the water supply is one of the important, if not the most important activity in the protection program. My own opinion is that the protection program will stand or fall depending upon the maintenance or non-maintenance of the water supply.

Incidents in this war thus far indicate that the enemy realizes the value of the public water supply from the defense standpoint and has directed his attack toward its destruction or control. The destruction of the water works of Warsaw during the first bombing raid was no accident; the destruction of the main supply lines at Coventry was no accident; the destruction of the water supply at Hongkong during the early bombing was no accident; and I could go on with other examples. The records to date indicate that the accident is when water works, other than distribution systems, are not damaged by bombing. It is my firm conviction that, if an air raid occurs in this country, the bombing of the water works will be a prime objective.

Much has been written about protective construction as it applies to essential water works structures. This has been interesting, but none too helpful in these times of scarcity of material, and will be less helpful in time to come when practically no material will be available. Your plans should be made, therefore, on the basis that you will have to get along with what you have. This applies not only to installation of protective measures but also to improvements and extensions. We are too prone to try and take advantage of the emergency to bring about improvements that have been desired for some time. Our job today is to win the war and our whole effort must be directed to that end.

Camouflage or protective concealment may be practiced at those plants that are particularly important to the war effort. If this is attempted, however, the advice of competent persons should be sought.

### Visualizing an Air Raid

In planning for an air raid, attempt to visualize the problems that may confront you. This I fear very few of you have done. First, you will not be handling the work in a manner to which you are accustomed, in that you will be operating as one unit in the protection program. Second, you will have to work in an area where many other activities are under way. Third, burning buildings, delayed action bombs and, possibly, flooding from sewers may interfere with your efforts. Fourth, you will have more breaks, visible and hidden, than you can at present conceive of, requiring many days, perhaps weeks, before restoration can be completed. Fifth, institution of repair work cannot be started until the over-all damage has been determined and repairs put on a priority basis in accordance with their importance. This will be after the raid is over.

Let us consider these statements briefly. If an air raid occurs, the protective activities will be under the direction of the Defense Commander. That includes activities of the water department. Is the water works properly represented on the Commander's Staff? Are such plans as you have made properly integrated in the over-all defense plans? Remember, someone on the Commander's staff is in charge of the activities pertaining to water.

During and following a bombing other facilities may be in the same predicament as the water works. Rescue workers, demolition squads and firemen may also be busy. Once broken mains are cut off, repair operations may be delayed for a number of reasons. Interference with permanent repair may be caused by broken sewers, burning or wrecked buildings, delayed action bombs or land mines.

How many breaks may we assume will occur during a raid? Have you considered this and made your plans accordingly? To me a reasonable assumption would be that in a token raid on a city of fair size, say 300,000 population or over, there would be 50 or more breaks, six to ten of them being in 12-in. or larger mains.

Let us look at a few records of bombing as they affect distribution systems. The following figures cover four cities of varying sizes. In two the damage was caused by one raid and in the other two by two raids within three days of each other: (1) Over 500 mains were damaged, more than 70 being of the larger diameters. (2) Over 200 mains were fractured, of which over 60 were trunk or feeder mains. (3) There were 40 breaks.

(4) Over 60 fractures were found up to two weeks following the bombing and 100 were dealt with before restoration was complete. You will note that fractures are not always readily apparent. This is important to remember in your planning.

## A Typical Incident

It is difficult for me, and I know that it must be for you, to picture just what damage a bomb does and the work necessary for the repair of this damage. I am, therefore, going to give you a picture of a single incident as it was told to me by the engineers who took charge following a bombing in a medium-sized city. This is given as a typical example, not the exception. Multiply it many times and you will then have some idea of what faces you if a bombing of your city occurs. Remember that during the bombing you will have little time or thought to give to repairs. Your energies will be directed to providing water for fire fighting and perhaps to essential industries. Mentally you may be disturbed because of the actual or possible bombing of your own home. This happens.

The incident was as follows: An H.E. bomb, probably a 500-lb. bomb, exploded near the center of the roadway. It formed a crater 30 ft. wide by 12 ft. deep. Four lines of tramway rails were broken and twisted across the crater. Fifteen feet of sewer was blown out, leaving the ends buried in debris. Fortunately, the sewer carried away the water, so flooding did not occur. Six yards of 15-in. water main was blown out, leaving the exposed ends tilted upward. Six yards of 6-in. water main was also blown out and 10 yd. of 18-in. gas main displaced and joints leaking. The latter could not be shut off.

Work on clearing the debris was started the morning following the bombing. Difficulty in breaking up the concrete and removing the twisted rails required bringing in a compressor, drills and metal-cutting equipment from an adjoining city. In spite of burning buildings and at least one shower of fragments from an exploding bomb, clearing was well under way on that day.

On the second day burning buildings alongside the crater made working unsafe, delaying the work until the fire could be controlled and the buildings demolished. When the excavation was cleared it was found that the pipe was sprung for a distance of 25–30 ft. beyond the crater. In spite of the delay, however, excavation was completed.

During the morning of the third day the pipe was laid ready for jointing when an unexploded 500-lb. bomb was found nearby. The military authorities stopped the work. It is interesting to note that the workmen had known of this bomb for sometime but had not stopped their work. Due to the urgency of the repair work the bomb was exploded instead of

waiting the prescribed time. Nearly a day's work was lost, however. On the fourth day the work was completed and water turned on that night. A few difficulties were encountered that day. The leaking 18-in. gas main could not be shut off and while every effort was made to minimize the escaping gas, eight jointers had to be used in turn to make the last joint, and at that one was overcome.

Thus the 15-in. pipe was repaired and the water on four days after the bombing. Remember this was a typical incident not the exception.

I have given in some detail what may be expected if an air raid occurs because my observations during these past few months have been that many of you do not realize what happens when the bombs fall. Naturally, bombings such as I have described have deprived parts if not all the city of water for longer or shorter periods. During such periods of interrupted service the water works officials are not relieved of the responsibility of providing water for fire fighting, industrial and domestic use. Have you planned for this? It is your job, you know.

### Chlorination in Wartime

The subject of wartime chlorination practice has received much discussion. All the information that we have from Great Britain emphasizes the need for use of chlorine over and above that normally applied. If the health of the consumers is to be protected it is necessary to have a disinfecting residual throughout the entire system at the time of, or immediately following, a bombing. The water in the distribution system at these times is subject to contamination in many and sundry ways. To increase the chlorine dosage when bombs begin to fall is too late. Chlorination of mains before restoration of service is, of course, essential.

At the outbreak of war the Surgeon General of the U.S. Public Health Service recommended that chlorine residuals be maintained throughout the distribution systems. It was realized that this could not be accomplished simply by increasing the dosage, but that study and experiments would be required at a majority of the plants. It was expected that you would take steps to learn how this could be accomplished. If you haven't made your plans relative to emergency chlorination so that they can be put in operation immediately if a bombing occurs, I would consider you negligent in your duties.

I was disappointed in the action taken by the A.W.W.A. Board of Directors (Jour. A.W.W.A., **34:** 468 (1942)) in connection with chlorination. It seemed to me that they held out a false sense of security to you. There are no "historical records" so far as bombing is concerned.

I have stated before that, if a bombing occurs, all activities are under the direction of the Defense Commander and only those persons properly

enrolled in the defense organization, who have proper identification and insigne, will be allowed on the streets. Have you enrolled the members of your organization, both regular and auxiliary, in the Citizens Defense Corps? Are they supplied with the proper insigne? Are your vehicles properly identified? Those of you who operate in more than one defense area must be sure that your personnel may move freely throughout the entire area covered by your system. This matter of enrollment and identification is of utmost importance—don't overlook it.

## Twenty Questions on Preparedness

Last April I set forth twenty questions having to do with water planning and operation in connection with air raid protection. These are, I believe, worthy of your careful consideration:

1. *Have you properly integrated your activities with the whole defense program?*

If not, you will have great difficulty in functioning during an emergency. Remember the Commander, Citizens Defense Corps, has charge of all activities during the emergency.

2. *Have you arranged for a representative of your department to be on the staff of the Commander?*

The Commander will need his advice as otherwise he may order action that is not compatible with good water works practice.

3. *Have you arranged for notification on an alert so that your force may be at their stations before the alarm sounds?*

If not, your force may never reach their stations or may arrive so late as to be of little immediate value.

4. *Have you arranged for proper identification of your emergency force under the civilian defense program so that they will not be interfered with by air raid wardens and auxiliary police while carrying out their duties?*

If not, you may have no emergency force immediately available when and where it is needed. These emergency officials may not recognize the usual forms of identification.

5. *Is your water works control or operating center properly tied in with the report or control center set up under the defense program?*

In Bristol, England, 95 per cent of the reports to water works were received through the report centers. Usual methods by which reports of breaks in water mains are made may not be functioning.

6. *Have you developed your own communications system so that it will function during a raid?*

Remember regular telephone service may be curtailed or may be entirely dead.

7. *Have you made arrangements for and are you training additional forces?*

London was obliged to double its repair and emergency crews. In many cases in this country the normal crews might have to be trebled. Plumbers, both master and journeymen, appear to be the logical group from which to obtain volunteer workers.

8. *Have you trained your own office and field force for emergency work?*

Office force, meter readers and the like can be used for gatemen and messengers if not for the more laborious work. Don't forget this requires planning and training.

9. *Have you placed any curb on the enlistment of your employees in other activities in the defense program?*

All water works employees should be trained for the emergency work of the department and not as air raid wardens and the like.

10. *Are your maps, gate valve locations and other essential data up to date and ready for use?*

You may need this information badly at any time.

11. *Have you checked your gate valves? Do you know that they will operate?*

No comment is needed on this question.

12. *Have you scattered your material and equipment at various locations?*

A single bomb may bottle up a central yard.

12. *Have you established stations in various parts of the city from which gate crews and minor repair squads will operate?*

Gate crews need to be at the incident as quickly as the firemen in order to operate valves and to report promptly the extent of damage.

14. *Have you arranged for chlorination squads?*

All mains must be chlorinated before being returned to service after repair, and auxiliary supplies that may have to be used must be chlorinated before entering the system. This must not be overlooked.

15. *Have you planned with the fire department officials for auxiliary supplies for fire fighting?*

This may be essential as broken mains may limit the amount of water immediately available in any area.

16. *Have you made provisions for supplying water to certain sections for domestic purposes during periods when water service is off?*

Use of water carts or temporary water lines may be necessary.

17. *Have you co-operated with the health department in your planning?*

Don't forget it is responsible for the health of the people.

18. *Have you carried on command post exercise?*

If not, how do you know your organization will function in an emergency?

19. *Have you arranged for increased laboratory examination of water samples from the distribution system as a regular procedure and for a much greater increase following an air raid?*

I do not need to stress the reason or necessity for this.

20. *Have you arranged to increase chlorine dosages so that proper residuals can be maintained throughout the system in case an air raid occurs?*

London has done this and maintained a better water, bacteriologically, than was the case before war was declared. This may mean auxiliary or booster stations. Don't forget that the human equation enters the picture and that chlorination of mains before being restored to service may not be perfect.

As heads of public water works you hold the most important position in the air raid protection program and upon you rests the responsibility of whether or not your city can resist a raid. You have always proved yourselves equal to any emergency that has occurred in the past. The citizens of your community are confident that you will be prepared to meet any emergency caused by bombing. Are you prepared?

# Chicago Civilian Defense Plans for Water Safety Control

***By Arthur E. Gorman***

WHEN in the spring of 1941 it became evident, because of the nation's lend-lease activities, that the large manufacturing, food supply and transportation centers of the United States were likely to receive the attention of Nazi sabotage agents, Chicago engineers began to give serious consideration to the potential hazards to the city's water supply system and to evaluate the relationship of this supply to the national defense effort. Careful studies and investigations established the poignant fact that Chicago's water supply system was vulnerable to sabotage and to damage by aerial bombing to a greater degree than had generally been realized. Since that time, however, this vulnerability has been reduced progressively, for Chicago has developed a comprehensive program for safeguarding its water supply system against possible enemy attack. This program is a co-operative one between various divisions of the Bureau of Engineering of the Department of Public Works. This bureau is charged with the responsibility for operation and maintenance of the Chicago water system.

In considering possible defense measures to safeguard the water supply, much was gained by studying reports of the effect and extent of damage in the bombed cities of Europe, but it is the author's opinion that, in making comparisons between European and American water works, care must be taken to place values on a sound relative basis. The problems and hydraulic considerations which exist in connection with the operations of European and American water works under both war and peace conditions are not strictly comparable. For example, in the European cities, buildings are not so high nor so large as those in American cities, per capita consumption of water is from 50 to 80 per cent less and treatment, storage and distribution systems and methods often vary widely. With an enemy less than fifty miles away, expecting some day to occupy an

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A paper presented on June 22, 1942, at the Chicago Conference by Arthur E. Gorman, then Asst. City Engr., Chicago, now Chief, Water Production Section, Power Branch, War Production Board, Washington, D.C.

opponent's territory, the potentialities for damage due to aerial bombs are vastly different from those which exist where long flights are necessary, where the probability of occupation is remote and where advance warnings can be received some time before air raids actually occur. A proper consideration of these differences and their relative significance is essential if a proper perspective of the relative hazards to American water works systems is to be established as a basis for planning protective measures.

## Evaluation of War Hazards

In Chicago, it has been attempted to evaluate water supply hazards in relation to the importance of the city in the nation's war effort and the vulnerability of the water works system to attack, whether by sabotage, aerial bombing or by both. First, it was endeavored to establish a vulnerability potential, then, to determine what would be required in men and materials to establish an adequate system of protection and control. On the basis of these values, an organization has been developed to function under what is considered to be serious aerial bombing.

The hazard potential (for any water works) is more or less a fluid quantity which can rise and fall with the fortunes of war and with the status of national and local defensive power. What may appear to be effective protection today or tomorrow may, in the light of subsequent developments, be wholly inadequate or precaution in excess. From studies in Chicago, it is evident that the maintenance of effective and adequate civilian defense of public water supplies demands the most careful integration of policies and planning between the civil and military authorities of any area or region, particularly one which includes a large city. This is a technical job of a high order. Unless it is carried out by experienced men, adequate community protection may be lacking and may result in an uneconomical use of men and material at a time when the best all-out war effort is needed.

## Relative Danger From Sabotage and Bombing

It is the writer's belief that it is much easier to plan to prevent and to provide against damage to water works from aerial bombing than from sabotage, even though damage caused by the former may be more destructive. In aerial bombing there is a wide element of chance and a great destructive potentiality; in sabotage, well planned and skillfully executed, the uncertain element of chance is reduced. The destructive force of sabotage may be less, but the damage potential at any point could be great, because sabotage efforts usually are selective for vital units in a water works system. Sabotage activities can strike at any point in a

water works system, from the source of supply to the local water system on the premises of an important individual consumer. The extent to which civilian defense work could be developed against sabotage to water works is boundless. A reasonable balance must be established between theoretical vulnerability and the cost (used in its broadest sense) of protective and control measures, each being weighed and timed in the light of war conditions. That water supply damage through sabotage could reach calamitous proportions cannot be denied by any well-informed water works or public health official. It is the obvious job of those in responsible charge of these important community functions to work in close co-operation with the military, naval and civil intelligence officials and *vice versa*.

It is difficult, even at this stage of the war, to evaluate the relative hazards to water supply by sabotage and aerial bombing. It would appear reasonable, however, to speculate that an enemy frustrated in aerial combat might resort to sabotage. With America serving as the arsenal, food source and training center for the United Nations war effort and with production now reaching unprecedented peaks, it is not at all improbable that experienced acts of skillfully directed sabotage will be committed against water supply systems. There is hardly a nation engaged in the war in which the damage and destruction of the water supply would be so serious as in the United States, for public water supply is the life-blood of community structure.

## Protection of Vital Water Works Structures

*Cribs*

To protect Chicago's six intake cribs, from two to four miles off-shore in Lake Michigan, special arrangements have been made with the Captain of the Port of Chicago to have the Coast Guard patrol boats pass the cribs at frequent intervals day and night. Armed Coast Guard men are stationed at each of the cribs.

No unauthorized person is permitted to come within 300 ft. of the cribs, signs to this effect being posted on the structures. Only regular city employees and persons having proper credentials approved by the U.S. Coast Guard are permitted on them.

Between each crib and shore two-way short-wave radio service is maintained for use in the event that normal telephone communications, using cable laid on the lake-bed, fails.

*Water Tunnel Shafts*

Under the lake and city are 53 miles of water tunnels through which the lake water received at the intakes is brought to the twelve city pump-

ing stations and the three smaller pumping stations operated by the Chicago Park District. Connecting these tunnels to the surface are 82 shafts, of diameters varying from 10 to 16 ft. Some are gate shafts, others, ordinary access shafts left open when the tunnels were built. Of these, 49 are within or adjacent to the grounds of the pumping stations, the remaining 33 being located at some distance from the pumping stations.

Practically all of Chicago's water tunnel shafts are vented for relief during surges. In many cases, sewers and public utilities pass close to the shafts and, in a few instances, the shafts are not far from the Chicago river or its branches. Although sewers and house drains in the vicinity of water tunnel shafts are made of cast-iron pipe, it is obvious that the destructive force of a high-explosive bomb could so damage the side-wall of a shaft and a nearby sewer as to permit gross pollution of water in the tunnel shaft. Therefore, it is essential that prompt measures be taken to check such pollution, if it should occur.

The possibility is also recognized that polluting materials—either bacterial or chemical—might be dropped or pumped into a water shaft through the vent or the access manhole. It would, however, require considerable advance organization and special equipment for persons not familiar with these shafts to gain access or to apply polluting substances in bulk or in solution. All tunnel shafts are now under day and night surveillance by roving police patrolmen afoot and in automobiles.

Because of the high rate of flow in the tunnels across any shaft opening, the effect of dilution would be great, and therefore the quantity of toxic substances which would have to be applied to affect consumers would be considerable. The results of salt tests, in studying the hydraulics of flow in Chicago's water tunnels, have revealed some interesting facts in regard to the prisms of concentration of soluble salts exploded *en masse* at the base of tunnel shafts. There is less inclination to be concerned over the application of chemical poisons to the shafts than to bacterial contamination. Even this possible hazard, serious as it may be, does not seem so likely in a campaign of sabotage as direct contamination of water in mains at selected points. The factor of time of flow from a shaft to the nearest pumping station gives some opportunity to apply protective measures against this method of polluting water in tunnels.

*Pumping Stations*

At the pumping stations visitors are not admitted without passes. Since December 7, 1941 one or more policemen have been on continuous duty at each station. Windows near certain vital equipment have been heavily boarded. It has been recommended that others be protected by heavy screens. Plans have been made to install fences and special light-

ing around all water pumping stations. These installations, however, will not be made until there is evidence of a more acute need for them.

*Feeder Mains*

There are 20 important river and canal crossings for water feeder mains. The pipes are laid in tunnels with shafts at each end. The special castings and fittings at the right angle bends at the top of these shafts would be difficult to replace. Therefore, all feeder mains under waterways are considered vital points, and their tunnel shafts are protected by police patrols in the same manner as the water tunnel shafts.

Special feeder mains supplying water to areas where vital war products are being made and where no loop system exists to allow water to be brought in from a secondary main in case the principal one is damaged are also under constant police surveillance. Anyone observed opening the street or any manhole to a vault, sewer or valve basin of a utility, is questioned for proper identification and detained if deemed suspicious.

## Emergency Chlorination

Much consideration has been given to chlorination of Chicago's water supply during emergency conditions, especially in the event that damage by aerial bombing should occur. The suddenness with which damage could be done, the uncertainty of where it might occur and the relatively short period of time which might elapse between the damage of certain structures and the introduction of large amounts of pollution into the water *en route* to consumers make it imperative that preventive and control measures be extensive and immediate.

Normally, a chlorine residual of from 1 to 2 lb. per mil.gal. is maintained in the Chicago tap water. During emergencies, such as main breaks or an excessive draft of water from the mains in fighting a large fire, it is customary to increase the rate of chlorine application at pumping station areas affected by 3 lb. per mil.gal. If warning of an imminent air raid is received, it is planned to increase the rate of chlorination at all city pumping stations 3 lb. per mil.gal. over that in effect at the time. When air raid warnings are received in a confidential report through civilian defense channels, the orders for increase in chlorination will be sent by the Water Purification Division in the usual manner; but when the only air raid warning is a public one as by means of sirens or whistles the operating engineers at the pumping stations, provided they have not received a previous emergency order, are authorized to increase the rate of chlorination immediately. Return to normal chlorination is to be made only on order from the Water Purification Division. Such orders will be based

upon reports of conditions in the water system as reported by special investigations to be described later.

### Use of Polluted Water During Emergencies

Consideration has been given to the proposition of requesting citizens to keep a small supply of city tap water on hand in bottles in every home, school, institution or industrial plant, to be used for a period of a few hours immediately following an air raid and until investigations and tests indicate that the tap water is safe. While it is conceivable that such action might become a necessary measure for civilian defense, it is one of the general items affecting the public on which action has been deferred pending more serious developments in the war. A protective program of this kind would require considerable preliminary development to explain the reason for it, to enlist public co-operation and to plan adequate communication channels for issuing proper instructions to citizens. It would, however, be much more satisfactory than to risk the hazards involved in an acute drop in pressure throughout the system during an air raid, resulting from public hysteria and from the withdrawal of water into bath tubs and other containers at the very time when effective water service and pressure would be needed to fight fires.

### Organization of the Civilian Defense Plan

The Chicago Civilian Defense Plan for Water Safety Control is directed primarily to protect the public health. It recognizes that, under Chicago conditions, contamination of the water supply could take place either directly or indirectly as a result of aerial bombing or sabotage. It is known as function "E" of the Public Works protective services in the comprehensive Civilian Defense Program for the Chicago metropolitan area. In reality, it is an expansion and a refinement of the normal emergency activities of the Bureau of Engineering, and it can be put into operation throughout the entire city or in limited areas.

In connection with the normal operations of the Chicago water works, a variety of emergency conditions threatening water supply service and safety must be met at all seasons of the year and under a wide variety of conditions. Major repairs to structures and equipment are made by the Construction Division, those to the distribution system are made by the Water Pipe Extension Division.* In either case, any exposure of the

* For a description of the defense activities of the Water Pipe Extension Division, see the discussion by B. W. Cullen in the August JOURNAL (Jour. A.W.W.A., **34**: 1210 (1942)).

water to pollution—potential or actual—calls for investigation and control by the Water Purification Division.

The problem of organization involved two major items: protection against aerial bombing and protection against sabotage. Plans for protection against both of these hazards were necessary so as to meet a wide variety of possibilities depending on war conditions as they might exist and on the availability of men and materials to carry out the protective measures.

## Responsibility of Public Employees

As in other cities, civilian defense of public works in Chicago is carried out by public employees. Therefore, logically, the protective activities to safeguard the quality of Chicago's water supply became a responsibility of the Water Purification Division. The personnel of this division at the time the Civilian Defense Water Safety unit was organized consisted of 15 sanitary engineers and chemists of all grades, 67 designing engineers and draftsmen, 17 stenographers and clerks and 18 inspectors, water samplers and laborers. To adapt this personnel to the expanded water safety program under civilian defense, required the delineation of the protective activities to be carried out and the organization and training of available personnel to perform the duties which these functions involved. This was done in February 1942 and was presented in a special civilian defense plan report submitted by the author to the City Engineer.

The work functions of the Chicago Civilian Defense Water Safety unit were planned, first, to give prompt coverage, during emergency periods, of vulnerable points in the Chicago water works system in order that the Chief Water Safety Engineer might know as promptly as possible the extent of damage and the public health risks involved and, second, to expedite emergency control measures for the protection of the public health.

## Organization of Personnel

It was realized that the prompt coverage of vulnerable points by trained sanitary engineers was impossible with the limited staff available. Therefore, it was decided to organize the employees in the Filtration Design Section of the division for this work and to train them in the duties required for efficient and effective performance. For the more technical work involved in emergency chlorination control, an organization was developed around the thirteen sanitary engineers in the Water Safety Control Section. The following is a summary of the number of Water Purification Division employees now assigned to water safety work on civilian defense:

| *No. of Employees* | *Water Safety Defense Titles* |
|---|---|
| 1 | Chief Water Safety Engineer |
| 1 | Assistant Chief Water Safety Engineer |
| 10 | Deputy Water Safety Engineers |
| 7 | Water Safety Technical Squad Leaders |
| 5 | Water Safety Field Squad Leaders |
| 25 | Water Safety Shaft Wardens |
| 15 | Water Safety Field Wardens |
| 18 | Water Safety Technicians |
| 1 | Water Safety Chemist |
| 2 | Water Safety Map Draftsmen |
| 5 | Water Safety Clerks |
| 11 | Water Safety Telephone Operators |
| 6 | Water Safety Messengers |
| 3 | Water Safety Chlorine Control Engineers |
| 110 *Total* | |

All emergency or warning calls from the Public Works branch of the Chicago Civilian Defense Organization are received at the division's 24-hr. station at the Dunne Crib Treatment Plant control station adjacent to the Experimental Filtration Plant. From there they are relayed to the Chief and Assistant Chief Water Safety Control Engineers in charge of the two headquarters units. These men call five key men, who, in turn, call from four to five others and so on until all 110 employees of the division are contacted. Tests show that the median time required to contact all employees is eighteen minutes. When not at home, employees keep their immediate superiors notified where they can be reached.

To provide for the necessary administrative units to receive official notification of warnings and to carry out all protective activities, two headquarters for the Water Safety Control Unit were organized. One, under the immediate direction of the Chief Water Safety engineer, is at the Filtration Design Section in City Hall; the other, under the immediate direction of the Assistant Chief Water Safety Engineer, is at the headquarters of the Water Safety Control Section at the Experimental Filtration Plant near the lake front and about eight and one half miles south.

The clerical staffs of these two sections are assigned the duties of receiving telephone calls, keeping records of reports from field wardens, making hydraulic calculations and contacting other divisions of the bureau or other city departments, as may be required, during the emer-

gency. Liaison officers have been appointed to maintain such contact as may be needed between the Water Safety Control Unit and similar organizations in suburbs, whether supplied water from the Chicago system or not. The chemical laboratory at the Experimental Filtration Plant is prepared to make special tests of the water, in case of suspected poisoning.

TABLE 1

*List of Miscellaneous Chlorinating and Testing Equipment Required for Emergency Use*

| QUANTITY | DESCRIPTION |
|---|---|
| 1 | 300 lb. per day gas chlorinator |
| 1 | 25 lb. per day gas chlorinator |
| 1 | Portable Proportioneer hypochlorinator—electric or water drive |
| 8 | Silver Tube main diffusers for chlorine |
| 16 | Assemblers for chlorinating direct from chlorine cylinder in water main, consisting of auxiliary valve, pressure gage and connection to corporation cock |
| 2 | Portable 300 lb. per day, emergency chlorinating trailer trucks |
| 3 | Portable hypochlorinators—gasoline-engine powered |
| 180 | Emergency field kits (complete) |
| 600 ft | Heavy-walled ½-in. chlorine hose |
| 600 ft. | Heavy-walled ⅜-in. chlorine hose |
| 600 ft. | Heavy-walled ¼-in. chlorine hose |
| 30 | Auxiliary chlorine valves |
| 20 | Chlorine gas masks |
| 2 | Complete 10-lead chlorine manifold assembly |
| 12 | Protective clothing suits |
| 48 sets | Rubber boots, coat and hat |
| 48 | Flashlights |
| 12 | Lantern (battery) |
| 900 lb. | Calcium hypochlorite 70% (H.T.H.) |
| 2 | Fresh-air gas masks with hose |
| 12 sets | Tools for emergency chlorination in chests |
| 7 | Short-wave radios for division-owned cars and chlorine control station |

While the personnel of the division was being organized and trained, it became necessary to supplement the equipment available for its normal emergency work. In particular there was need of special fittings for applying chlorine gas and chlorine solutions to water mains and to tunnel shafts. Two trailer chlorinators were also under order. In Table 1 is given a list of emergency equipment which is being obtained for civilian defense in protecting the safety of Chicago's water supply.

### Water Safety Shaft Wardens

To carry out the work of checking on all tunnel shafts, five squads of water safety shaft wardens have been organized among employees of the Filtration Design Section. A tunnel captain is in charge of each of the four major tunnel systems. Under him are the shaft wardens, the number in each squad depending on the number of shafts on the particular tunnel system. In the case of the southwest land tunnel system, which has two major branches and 27 shafts, the organization calls for two squads.

When warning of an imminent air raid is received, each shaft warden goes at once to the shaft to which he has been assigned. The tunnel captain reports at a pumping station near the middle of the tunnel system. If the warning is received during office hours, the men are sent out by whatever means of transportation is available—automobile, street car, elevated or on foot. In certain emergencies, taxis might be commandeered. If the warning is received by telephone at home, the wardens proceed in a similar manner. As the men are assigned shafts reasonably near their homes the time required to arrive at their posts of duty is less than when they are at work. In the event of an official civilian defense alarm by siren or whistle, the shaft wardens go directly to their assigned shafts.

Each shaft warden has at his home a carrying case containing a 5-lb. can of "H.T.H." or "Perchloron" and a set of sterile bacterial sampling bottles. It is his duty to arrive at the shaft as promptly as possible. If he arrives prior to an aerial bombing he must station himself at a sheltered point, a reasonable distance away. If he arrives after a bombing, he must check at once on the condition of the tunnel shaft. If damage has been done to the shaft and polluting material is entering it, he must do all that he can temporarily to safeguard the water supply by pouring the chlorine sterilizing compound from his emergency kit into the shaft. He must then check, as best he can, the inflow of pollution by enlisting the aid of others who arrive at the scene of the accident. After rendering this first aid service, the shaft warden must telephone water safety headquarters, reporting the time and extent of damage and any helpful information which may be indicated as desirable for relay to the technical squad or squads which will be sent to the scene to direct public health control measures. Knowledge of the exact time of the incident is especially important, for then the time of arrival of this polluted water at the next pumping station can be established and instructions given for super-chlorination at that and other pumping stations which would be affected.

Each shaft warden has been given intensive instruction in emergency chlorination, the hydraulics of flow through the tunnel system, the pumpage characteristics of the stations supplied, the physical details concerning

the particular shaft to which he has been assigned and the type and location of utilities in the vicinity of that shaft. He knows the location and officers of the nearest police station and firehouse on whom he can call for aid or through whom emergency telephone messages can be sent or received. In case of actual shaft destruction, the reason the shaft warden calls water safety headquarters first is to expedite the transmission of orders for emergency chlorination and the immediate dispatch of the technical squads. In all other cases the shaft warden calls his tunnel captain, who in turn, reports conditions on the particular tunnel system under his charge. The Chief Water Safety Engineer will not issue an order to reduce emergency chlorination to the normal rate at stations served by a tunnel system, until he has received a report from the tunnel captain. By this system of check and reports, Chicago's tunnel system will be safeguarded during emergencies.

### Water Safety Field Squads

A second group of employees in the Filtration Design Section has been assigned to duty in Water Safety Field Squads. There are eight squads, each in charge of a leader, under whom are assigned four or more assistants known as Water Safety Wardens. They are trained in emergency chlorination, in making ortho-tolidine tests for residual chlorine, in the interpretation of results obtained under field conditions and in collecting samples of water for bacterial and chemical analyses. Each has assigned to him a portable field testing kit consisting of a carrying case, a supply of ortho-tolidine with pipettes for measuring, a set of residual chlorine color standards, a 5-lb. box of "H.T.H.," a supply of sterile bacterial sampling bottles —with and without thiosulfate for de-chlorination—and labels and cards for identifying samples collected.

In certain sections of the city these field kits are left at conveniently located fire stations at which squads assemble; in some cases the kits are kept at the Water Safety Warden's own home. A reserve supply of kits is also kept at the two headquarters' sections of the division where the men are regularly employed.

The Water Safety Wardens are sent into the field to check up on conditions in an area where damage has been reported. They make residual chlorine tests, collect chemical and bacterial samples, note pressure conditions and report results to their squad leader. He, in turn, reports to the water safety headquarters, where records of field test and observations can be reviewed and posted on charts and diagrams for control purposes. Should serious pollution of the water occur and chlorine applied for disin-

fection be absorbed, the reports by these wardens, will make it possible to determine those areas where public health hazards are most acute. A comprehensive field picture in connection with chlorination control measures can be obtained by the reports of ortho-tolidine tests made by these men on samples from selected points in the distribution system. In effect, these wardens perform under emergency conditions work similar to that done each day by the division's three water samplers. If, in the opinion of the Water Safety Engineer, field conditions indicate the possibility of a water-borne outbreak, all facts would be reported through civilian defense channels to the proper health authorities.

## Technical Squads

There are eight technical squads, each in charge of a junior sanitary engineer experienced in field work pertaining to chlorination and a variety of water safety control functions. In response to an emergency civilian defense call, these employees report to the Water Safety Headquarters at the Experimental Filtration Plant. There, stored in special cabinets, is a complete set of emergency equipment, including protective clothing for each squad. These squads are provided with city-owned automobiles used regularly by engineers and water samplers and stored in a garage adjacent to the Experimental Filtration Plant.

The duty of these men is to carry out the highly technical work required during an emergency to safeguard the public water supply. If a pumping station were bombed and chlorination equipment destroyed, these engineers would be prepared to chlorinate the water flowing through the supply tunnel to the station by applying chlorine to a shaft. Likewise, if a shaft were damaged and polluting material discharged into it, these engineers could apply chlorine to this shaft at any rate which might be required.

If a feeder main were broken and an emergency bypass connection made around the damaged section, these engineers would be prepared to chlorinate the water in the main under control conditions until safety to the public health could be assured. This emergency chlorination would be done in full co-operation with the repair crews of the Water Pipe Extension Division, following procedures similar to those carried out after main breaks in the distribution system. The Water Pipe Extension Division has expanded its emergency repair service field stations from three to seventeen, distributed at various strategic points throughout the city. When called during an emergency, the repair crews report to these stations where special equipment is on hand for emergency work. That division is organized to repair six major feeder main breaks within 24 hours.

Should water service to one or more large buildings, especially in important industrial or commercial districts, be shut off while repairs are made, the Water Pipe Extension Division is prepared to supply water temporarily by making fire hose connections from nearby fire hydrants outside the area affected, or to lay an emergency surface main with temporary connections to the principal buildings. In this case, the water safety technical squads would sterilize the hose and temporary pipe lines and control chlorination of the water supplied through the temporary services. Frequent tests for residual chlorine would be made and samples collected for bacterial analyses.

When a water main in a street is broken the rapid drawdown of water in the riser pipe supplying the water system on various floors of buildings may cause a considerable negative head to occur in water pipes to fixtures. This could cause back-siphonage, with serious contamination of the local water system. It would be the duty of technical squads to investigate these hazards and to chlorinate the local water supply in these buildings. Occupants would be advised not to drink the water until notice was given of the safety of doing so.

There are numerous places in a water distribution system where loss of pressure could create serious health hazards due to negative head conditions lasting only a few seconds. The junior sanitary engineers are aware of most of these vulnerable spots and have been instructed to give special consideration to control measures in these areas.

## In-Service Training

It has been necessary to conduct special in-service training courses to instruct employees in their duties in the civilian defense plan. This has been done by lectures, field demonstrations, group discussions and by practice in responding to hypothetical air raids. Certain general lectures pertaining to the organization of the department and bureau and the civilian defense effort in Chicago have been given to all employees. A large percentage of the Division's employees are now taking the Red Cross 30-hour First Aid Course. Special lectures on the properties of chlorine and demonstrations in making ortho-tolidine tests, collecting water samples and reading simple instruments used in water works, have been given to the waterwardens.

The shaft wardens have been given a more intensive course of lectures and field work designed to familiarize them with the supply system, the hydraulics of flow in the tunnels, the characteristics of pumpage at the various stations, the potential hazards in the vicinity of tunnel shafts, the layout of shafts and nearby utilities and effective means of rendering

emergency first aid in case of damage to a supply tunnel shaft or a river crossing tunnel shaft. The tunnel captains are picked men and have been given the intensive training given junior sanitary engineers in charge of technical squads.

Prints were made of each tunnel shaft, showing in detail its physical dimensions, materials and the location of all nearby utilities. Each shaft warden has a print of the particular shaft to which he is assigned and each tunnel captain has a set for all shafts under his charge.

## Identification Badges

Under orders from the Commissioner of Public Works, all employees of the department have identification badges which must be worn at all times. The badges which are $2\frac{1}{2}$ in. in diameter are issued in three different colors: white for executives, blue for supervisors and green for ordinary employees. On the face of the badge is shown an identification number and a photograph of the employee against a white background calibrated in feet and inches and also showing a seal of the City of Chicago. Before the badges were issued, a record of the fingerprints of each employee was sent to the F.B.I. for review. Employees whose duties require them to go to the cribs, ride tugboats or perform work on the lake front are required to carry identification badges issued by the U.S. Coast Guard Service. They contain a photograph and description of the employee and fingerprints.

The Civilian Defense Co-ordinator for the Chicago Metropolitan Area is Mayor Edward J. Kelly; the Chief of the Protective Services is Ralph Burke, Chief Engineer, Chicago Park District; the Public Works Services are under the direction of Oscar E. Hewitt, Commissioner of Public Works; the Water Supply Co-ordinator for Chicago is W. W. DeBerard, City Engineer; the author, as Assistant City Engineer is Chief Water Safety Engineer and H. H. Gerstein, Assistant Chief Water Safety Engineer.

# Investigations of Water Works Protection in Ohio

*By W. H. Knox*

PRIOR to December 7, 1941, the Ohio State Department of Health had already planned and undertaken a program for a survey of the more important water works systems in the state to determine what precautions were being taken and what additional steps needed to be taken for protection of public water supplies in the event of war. The declaration of war speeded this program. During the early months of 1942 other work was postponed and every member of the Engineering Division spent a major portion of his time on these surveys. By the middle of May a special investigation had been made of the water works systems of 75 cities and 16 of the larger villages in the state.

Rather than outlining the various precautionary measures to be taken, the author proposes to discuss some of the actual conditions encountered in the surveys undertaken. The most surprising feature of these surveys was that, except for special war measures such as guarding, fencing and lighting, the precautionary measures required are only those which should be practiced at all times in any well operated water works system.

The conditions found varied widely. In a few instances it appeared that city officials had become unduly alarmed and the guards, lighting and other precautionary measures taken seemed out of proportion in relation to the structures being protected. In most instances, however, the water works officials had already taken measures to provide reasonable protection within the financial ability of the city. In a few cases no protective measures whatsoever had been adopted, the city officials having an "It Can't Happen Here" attitude.

## Importance of Records

The outstanding defect noted was the appalling lack of records at a large number of municipalities. This is a feature of water works systems that has not ordinarily been investigated by members of the department. The

A paper presented on May 14, 1942, at the Ohio Section Meeting, Toledo, Ohio, by W. H. Knox, Asst. Engr., State Dept. of Health, Columbus, Ohio.

fire underwriters have, however, stressed this item and a review of their reports shows that many cities have neglected the subject for years. It is difficult to understand how the head of a water works department would not be continuously uneasy unless he had a permanent and accurate record of the mains, valves and connections in the distribution system. It is only fair to state, however, that most of these instances occurred where there was no actual water works superintendent, the director of public service attempting to fill this position, or where there had been a frequent change in superintendents. The best records observed by the writer were those maintained by private water companies and those of systems formerly owned by private water companies where maintenance of adequate records had been continued under municipal ownership. In several instances excellent records had been compiled but were not properly stored. Originals should be kept in a fireproof vault; only copies should be used in the field.

When the investigators asked to see the record maps of the distribution system, in some cities the maps of the fire underwriters were displayed, these being the only available records of the distribution system. In the fire underwriters' reports, the maps of small villages are on a scale of 1 in. to 500 ft. and, in addition to sizes of mains, show the approximate location of valves and hydrants. Such maps would be of considerable assistance during an emergency if no more detailed records were available. In medium-sized and larger cities, however, the fire underwriters' maps are on a scale of about 1 in. to 1,600 ft. and therefore do not show valves and hydrants. These, of course, would be of little value during an emergency. In one city where only the fire underwriters' maps were available, the city was without water during a period of over 24 hours because a valve on a broken main could not be located and the reservoir drained.

At another city the writer asked the director of public service how the valves to be closed on a broken main were located and was informed that the foreman knew where all of the valves were and that he was notified. The fact that this valuable employee might die or resign and cause his information to be lost to the city did not seem to worry the city officials. In some instances such employees have refused to divulge their information in the mistaken idea that the tenure of their jobs depends on having information which is not available to anyone else.

It is to be hoped that the war emergency will cause municipalities to establish and maintain the accurate and permanent records of distributing systems which should always have been maintained.

Another feature noted was the rather indiscriminate distribution to laymen of information regarding the water works system. Such information is strictly confidential and should be carefully guarded. Civilian defense

organizations often were furnished maps of the distribution system and some such organizations anticipate that they may take charge of a water works emergency by closing valves, etc., in the event that mains are broken by bombing. The fullest support should, of course, be given to civilian defense organizations, but laymen might be of more harm than assistance in such cases. Except in small villages there are always several water works employees who are familiar with such work. The names of such employees can be furnished to civilian defense organizations. If there are several competent employees, it is certain that at least one can always be reached to supervise any emergency work to be done.

Another important item is that records should be available 24 hours per day. If duplicate copies of records are not furnished to a trusted foreman, copies should be kept at some place such as the police station or fire department which is always open.

### Necessity for Guarding

It is possible and feasible for practically every water works to adopt measures to prevent sabotage by an amateur or a "crackpot." Such persons have little or no knowledge of the vulnerable points of a water works system and any damage done by them is likely to be slight and temporary. It would be highly desirable if all publicity concerning attempts to damage a water works could be eliminated; such publicity only gives other amateurs or crackpots ideas which they have not had before.

The guarding of water works structures to prevent sabotage by a professional presents a different problem. Very few municipalities can afford to hire guards to patrol all vulnerable points at all times. In such cases guards have been provided at the most vital places, regular and frequent inspections are made of all features of the water works and repair parts for emergencies are kept on hand.

Fortunately, it generally requires considerable time and labor to effect major damage to water works structures. Frequent and regular inspections will reveal whether there has been any tampering and whether suspicious persons have been seen in the vicinity. If it is impossible to provide regular guards it is always possible to have police cruisers include water works structures in their routine inspections.

At one small city visited by the writer the regular water works employees are four in number. The hiring of guards to protect the two main features of this system would more than double the labor item. If the cost of guards must be paid for from water revenues, the superintendent estimates that rates would have to be increased at least 50 per cent. It appears that some provisions should be made for paying guards from sources other than from water revenues where important water works are to be protected and where the city water department cannot afford the expenditure.

The writer is firmly convinced that guards should be under police supervision and that the caliber of the guards should meet the requirements of police officers as nearly as possible. In at least one instance there was a suspicion that jobs as guards had been given as political considerations.

## Protective Lighting and Fencing

Often the protective lighting which has been installed demonstrates even to a person who is unfamiliar with lighting requirements, that more effective lighting could be provided. The best advice to water works officials is that they consult the local electric company. The company almost always has some engineer who is an expert on lighting. Such experts are not interested primarily in selling fixtures or current. Where such advice is sought the protective lighting problem of water works structures can be solved at a lower first cost and also at a lower operating cost than if the water works officials attempt to do this work without competent advice.

Several instances have been noted where lighting would better have been omitted. Some lights call attention to vital points which would not have been known to anyone except an expert unless the lights had been installed.

In general, merely lighting a water works structure is of rather doubtful value if guarding is not also provided.

Wartime protection has resulted in erection of protective fences around many water works properties. Some of such fences can be regarded as necessary only during the war period. Many, however, should have been installed as a protective measure during ordinary times.

Fencing as well as lighting does not in itself provide protection for structures unless guarding is also maintained.

## Availability of Spare Equipment

About 75 municipalities have furnished the State Department of Health with inventories of material on hand. In general, these inventories show that most municipalities keep on hand lengths of pipe and sleeves of all sizes used. Most of the water works also keep in stock at least one valve of each size and a small stock of special fittings. Practically no water works has any surplus equipment which they would be willing to lend or sell to a neighboring municipality unless there was assurance that the equipment could be replaced at an early date.

## Water Service to War Industries

During the surveys lists were compiled of the important industries in each municipality and those firms engaged on war contracts. It was surprising to learn that almost every industry which is now operating is directly or indirectly connected with the war effort. Even in some smaller

villages vital parts of war products are being manufactured by small firms having only a small number of employees. These firms had previously manufactured articles which to the layman appeared to have little relation to the war products being manufactured.

A record was obtained as to whether these firms depended solely upon the public water supply or whether an auxiliary supply was maintained. It was learned that in almost every instance maintenance of the public water supply was essential to the operations of the industrial plant. The auxiliary supplies present two questions to water works officials: (1) whether the private water supply is improperly cross-connected to the public water supply mains; (2) whether industrial supplies might be available and suitable to supplement the public water supply during an extreme emergency such as bombing. Water works men are naturally loathe to have any other water pumped into city mains. During the 1913 and the 1937 floods, however, several public water supplies had to be supplemented in this manner in order to furnish any water to the consumers. Such auxiliary sources and their possible use should be investigated.

Another important item that has been neglected in Ohio is the connection of the water mains of two adjacent municipalities so that one can provide at least a partial supply in case of breakdown of the facilities of the other system.

Many other features of water works protection, among which are the investigation and identification of personnel, power facilities, communications, fire protection, chlorine storage and handling, etc., are being practiced in Ohio cities. One of the most important items regarding any protective measures being taken is that no publicity concerning such items should be permitted. A consultation with local newspapers will secure their cooperation in this manner.

The surveys of the department have shown that almost all of the water works officials in the state are alert to the special problems facing them during the war period. It may require actual sabotage or bombing to awaken a few of them to the fact that we are in a war and that all precautions possible must be exercised.

In general, the department investigators have received excellent cooperation from local water works officials. It is believed that, if present efforts to protect water works are continued and are improved upon as circumstances permit and as the occasion demands, the water works systems of Ohio will be prepared to meet any emergencies that may occur during the war period.

# Current Supply Problems

### *By E. F. Dugger, G. L. Fugate and Marsden C. Smith*

### Newport News—E. F. Dugger

EARLY in 1940 Newport News realized that the preparations for national defense were going to necessitate major extensions to its plant and supply facilities. The shipyard had at that time received contracts which called for a tremendous increase in employment. Conferences with Navy and shipyard officials clearly disclosed the necessity of immediately enlarging the water facilities of the area. Since early completion of the project was imperative, plans for the development of an additional water supply and transmission mains were quickly prepared. From January 1 until the passage of the present Lanham Act, it was impossible to secure government aid in financing projects directly connected with the Defense program.

Immediately upon the passage of the Lanham Act, the Newport News project was filed. As a result of Navy approval, this project was approved and a priority rating of A-3 was assigned. The contract covered approximately 17 mi. of cast-iron pipe, a 6-mgd. filter plant, pumping station and necessary appurtenances. At this early date little or no difficulty was encountered in securing the necessary materials with this priority. However, the FWA was advised by the city at the time this project was approved that a continued drought or any enlargement of the present program would necessitate securing additional water to meet demands of the Newport News area.

The original project was put in operation this past summer. In December of last year it became apparent that an additional supply of raw water would have to be secured. Following studies and surveys by the city's

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A round table discussion presented on June 24, 1942, at the Chicago Conference, by E. F. Dugger, Gen. Mgr., The Newport News Water Works Com., Newport News, Va.; G. L. Fugate, Chief Engr., Water Dept., Houston, Tex.; and Marsden C. Smith, Chief Engr., Dept. of Public Utilities, Richmond, Va. W. W. DeBerard, City Engr., Chicago, and T. T. Quigley, San Engr., Wallace & Tiernan Co., Inc., Newark, N.J., also participated but submitted no written discussion in time for publication.

engineers, it was decided that a river supply approximately 31 miles northwest of the present reservoirs would be the answer to the problem.

In February application was made to the Federal Works Agency for funds to cover this project. It was promptly approved and contracts for this additional supply have been made. Construction on the major portion of it is now under way. This project was assigned an A-1-C priority.

As previously stated, the first project was given an A-3 priority, but as many of you will realize, an A-3 priority last December probably equals an A-1-C today. As a matter of fact, it has been necessary to increase the A-1-C to A-1-A in order to get required deliveries. A drought plus an increase in demand on the system and continued urgent demand for extensions to the plant's facilities created many serious problems. These problems were multiplied because of the difficulties in getting materials.

The supply problems in a defense area such as the tide-water section of Virginia do not concern this organization to any great extent. Whatever the situation may be in a given defense area, the Navy, Army or other branches of the armed forces directly interested in the program will see to it that adequate priorities are secured.

We realize each day the necessity of privations individually and as communities in order that the war effort may proceed to a speedy and successful conclusion. We are willing individually and collectively to make such sacrifices in order that our armed forces may not be handicapped in any way. We are fully aware of our responsibility. The war effort in defense areas and indirectly in non-defense areas must have sufficient material so that the water supply—the most vital utility within the municipality—will not be handicapped. In this way the war effort will not be prejudiced or curtailed because of lack of materials.

## Houston—G. L. Fugate

UP TO the present time no substitute materials have been used, except for copper tubing. For several years it has been a standard practice to use copper tubing for all 2-in. and smaller connections, extending in length for the street width and for all service lines, both new and replacements from the mains to the meters. Before these standards were adopted, lead goose necks of the conventional type, and galvanized pipe had been used.

In September 1941 a large delivery of copper tubing was received on an order placed in June. Anticipating that this delivery might be the last for some time, standards were changed to conserve the tubing and use it for connections to mains only.

These standard lengths are used now: $\frac{3}{4}$-in., 3 ft.; 1-in., 4 ft.; $1\frac{1}{2}$-in., 5 ft; and 2-in., 6 ft.

Galvanized pipe is used to complete the connections for sizes less than 2-in. The new connections have averaged about 265 monthly for several years. The late standards have resulted in saving, during the first 5 months, of over $3\frac{1}{3}$ mi. of tubing compared to the same period last year, or about 52 per cent. Of course, the quantity of galvanized pipe used has been increased accordingly but so far no difficulty has been experienced in securing this kind of pipe. Although a freezing order on new buildings not essential to winning the war has been issued, new connections for the first 15 days of June decreased only 26 per cent. It is assumed that most of these were buildings started before the freezing order became effective, and that records of the next month and thereafter will show a much greater decline. If so, the copper tubing will last well up into this year. Some consideration has been given to the use of a lead alloy product to replace copper, if it is obtainable when the present supply of copper is exhausted.

## Richmond—Marsden C. Smith

MOST water works operating engineers today find themselves in a position that is as strange as though they were attempting to transact business in a foreign country. It is useless for us to discuss the causes of this situation or to waste time in bemoaning the fact that we are in the midst of a truly "all out war."

It also seems useless to bother you with a recital of the various problems with which we are confronted. And surely, the manufacturer can best describe the substitutes that may be used to replace those materials to which we are accustomed.

### Purification Problems

There seems to be no practical means now available for the reliable sterilization of water supplies other than chlorine and its compounds. Since the War Production Board recognizes this fact, we may assume that sufficient chlorine for sterilization will be available for the duration of hostilities.

So, for those of us using chlorine gas, our procurement picture remains unchanged. Adequate supplies are available and seem assured in the future.

But while sufficient supplies are procurable, the hypochlorite form may have to be changed due to the likelihood that nearly all of the high test hypochlorites will be needed for the protection of the health of our expeditionary forces.

Realizing the problems of transportation and storage of chlorine supplies to these forces, it is obvious that the concentrated, stable hypochlorites should be allotted to this all important use.

Looking ahead it appears that for public health and military requirements in the United States itself we may have to return to our old friend, chlorinated lime, for the duration. It will be made more usable by improved packages and its stabilization improved. Such a necessity may cause some inconvenience but no serious problem. We should remember that calcium hyperchlorite is the same in effect regardless of its form. Only the strength, stability and sludge formation vary. Hence while dissolving practice must be modified, feeding and control will remain the same as for the high test now in general use.

For coagulation we have a wider selection, the best known being:

1. *Sulfate of alumina*, the most popular, but consumes in its manufacture aluminum ore and sulfuric acid, *both* of which are critical.

2. *Ferric chloride*, which requires chlorine and steel scrap for its manufacture.

3. *Ferrous sulfate* (chlorinated) is a waste product, but uses chlorine for its oxidation.

4. *Ferrous sulfate* (with lime), of which one is a waste and the other an abundant material.

5. *Ferric sulfate*, presumably a waste material.

From this partial list, it is evident that there are coagulants available to water treatment plants that consume no critical chemicals, or at least permit a selection of chemicals. It is admitted that the change to a new coagulant in any plant will require much and hard study and even some changes in plant design; but certainly here is a possible way to help if the need should ever become so acute as to require the risk involved in such a change.

For the many plants that are using alum, it may be of interest to know that the writer was recently privileged to study a filter alum derived from a low grade of bauxite. This alum gave highly successful results, even though its analysis was a far cry from the standard product. Hence, we may find ourselves releasing all high grade bauxite for essential war purposes and, by research and effort, learn to use a strange but effective "sub-alum." (Specifications for this type of alum were approved as an alternate to standard water works filter alum by the A.W.W.A. Board of Directors, June 25, 1942, for which see pp. 1073–74 of the July JOURNAL. WPB Order M-1-h issued on July 7, 1942, restricted the distribution of high grade bauxite.)

The other supplies and materials generally used in water purification are not essential and, therefore, if they should become unavailable, will

cause no direct threat to public health. Of course, there exists the possibility of driving consumers to unsupervised sources of drinking water because of the unattractive quality of some of the purified water that would follow the withdrawal of these auxiliary but highly important chemicals.

## Pumping and Distribution Problems

The available substitutes in operating supplies used in pumping stations are limited. Fortunately, the use of critical materials in these stations is relatively small. Also, it is certain that the rationality of any major substitution, such as electric drive for oil in rationed areas, can be easily determined.

In the distribution system, we are confronted with problems that involve not only materials, but also limitations in the design. Of course, we should not object to a fair limitation in design, nor to the substitution of non-critical materials that can be expected to give a reasonable service. But we cannot escape the unfortunate fact that such a vastly greater part of the cost of a completed water system is in the labor and paving charges than in the materials themselves. Consequently, we are in a different position from the electric company. For them it is a relatively simple matter to replace overhead steel wire with copper when the latter is available, while the use of all iron valves and undersized mains and services will, in most instances, be equally unsuccessful and their replacement will cost even more than the cost of installation.

The War Production Board is certainly correct in making every effort to limit new construction to an irreducible minimum and certainly in the *need* of materials, the winning of the war demands a prior claim for that purpose over all others.

But it is equally certain that even the War Production Board may find errors in the determination of the actual *need*. For example, there could be no doubt that much of the work that is being done in our war effort is definitely of a temporary nature. Surely, many of the camps, industrial plants and defense homes will of necessity be abandoned as soon as the war is over. Why then should not all construction of such a definitely temporary nature be made to use temporary materials?

If that be done and new construction be limited as severely as is possible, it seems quite probable that the relatively small demands for the construction and maintenance of permanent water systems could be allotted the small amount of critical materials needed for proper service.

# Importance of Salvage to the War Effort

### *By Clayton Grandy*

THE war effort has entered a new phase that demands wholly new concepts of action. The unprecedented requirement which this change puts upon war industries to produce fighting equipment *for full scale action this year* means an unprecedented consumption of materials and an imminent crisis in their supply.

Every classification of industry, every plant executive, is confronted with an imperative appeal to salvage *more* iron and steel scrap, *more* non-ferrous metal scrap, *more* rubber, *more* cotton and wool waste—*more* of all the materials needed to make fighting tools.

As an introduction to the important subject of industrial salvage, a few facts and figures covering the need for raw materials and scrap by the industries engaged in producing war supplies should be reviewed.

For the manufacture of the implements of war—planes, tanks, ships and guns—enormous supplies of metals are required. The Victory program designed by the War Production Board means a continuing and increasing drain on raw materials, which must be supplemented in every way possible.

Last year the nation produced some 80-odd million tons of steel. Only a quarter of this was for war and lend-lease use. This year the need is for more than 90 million tons. War needs for copper between now and the end of 1942 are estimated to be five million tons. Regular normal sources of supply will provide about three million.

The only way to solve this whole production problem is to get into the flow all the scrap out of which raw materials can be produced. The critical materials most urgently needed today are iron and steel scrap and non-ferrous metals, such as aluminum, copper, brass, zinc, and manila rope, rubber, burlap, waste paper and cotton and woolen rags.

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A recapitulation of various addresses by Clayton Grandy, Trade Association Director, Industrial Salvage Section, Conservation Division, War Production Board, Washington, D.C.

Under normal conditions, iron and steel scrap provides for about one-half the steel produced. To produce the 90 million tons of steel referred to above, at least 32 million tons of iron and steel scrap are required.

At this point a word of explanation regarding the operation of the Bureau of Industrial Conservation, of which the Industrial Salvage Section is a part, is in order. The four branches of the bureau are: (1) Simplification, (2) Substitution, (3) Specification and (4) Salvage. The first two are more or less self-explanatory. Specification applies to the regulations employed by the government in the purchase of all materials.

## The Salvage Branch

The fourth branch—Salvage—is the one with which this paper is mostly concerned. The operations of these four branches comprise the entire activity of the government for conservation.

The salvage branch is divided into four separate operational units: (1) Industrial; (2) General, or Household, which handles the removal and disposal of scrap materials from homes, retail stores, farms, garages and the like; (3) Automobile Graveyards; and (4) Special Projects. The last mentioned, Special Projects, deals with unusual problems, such as buried rails, abandoned buildings, properties containing scrap materials, ownership of which is in legal hands or unknown.

The author's particular function is Industrial Salvage, which is concerned with promoting the flow of all scrap materials—all kinds and types—from all manufacturing plants and establishments, mines, mills, public utilities, railroads and oil wells. This applies to scrap generated in the process of manufacturing and also to that which can be realized from the wrecking of obsolete and abandoned machinery from unusable stocks, dies, parts, etc.

The Industrial Salvage Section was set up and staffed with several specialists, thoroughly experienced in salvage operations of all phases. The objectives of the section are:

1. To educate industry to salvage all critical waste materials
2. To speed up the return of these materials into the "bloodstream" for war production purposes
3. To advise and help industry to use established channels in disposing of these waste materials.

An all-out campaign, whereby every industrial organization will be reached, has been placed in operation, and the section is definitely committed to the accomplishment of its objective—*to get every ounce of needed material moving.*

The salvaging and collection of scrap is a normal procedure in business and industry. It is well known now, however, that normal sources of

scrap cannot deliver the quantities needed to fulfill the demands of the war program. Several industries, such as the automotive, that have supplied scrap in large amounts in the past cannot continue to do so, since they are now engaged 100 per cent in war production of planes, motors, tanks, ships and guns.

## Need for Executives' Co-operation

Probably the greatest problem of the Industrial Salvage Section has been to get the top executives of industries of the country to recognize that the matter of salvage is a serious problem. The story must be "put across" to the men who can make immediate decisions and take action most quickly. The heads of companies must be persuaded to give to purchasing agents, to salvage managers, to plant superintendents, not only the responsibility of salvage today, but the authority to do the job as well. Experience has indicated that, at this time, the principal failure of scrap materials to be located and moved has been that the authority and responsibility has not been placed with the proper plant committee or individual.

Very simply stated, the assignment of the Industrial Salvage Section is to get the attention of every president, of every shop foreman, of every workman in every plant in the country to the crying need today for the many materials mentioned previously. An attempt has been made to concentrate, as the tide changes, on those materials that are at the moment most critical. For example, unless it is possible to push more rubber scrap in tremendous quantities into the market, all the rubber reclaiming plants will be forced to shut down in a very short time.

It is true that in certain localities, for price reasons or other, there is no shortage of some of these materials; but in the aggregate these materials are vitally needed. In some cases there is no actual shortage but a dislocation.

The spotting and movement of scrap to the mills is the only way known to augment the great deficiencies of certain raw material supplies today. It is estimated that for the year 1942 there is an iron and steel shortage of some six million tons. Many open hearth furnaces have already been shut down due to shortage.

Following a talk presented in the West a few weeks ago, the president of a steel company announced: "In this area there are four furnaces down, not for repair, but because there is a shortage of iron and steel scrap. These furnaces have a total capacity of 700 tons per day. In the building of a 10,000-ton cargo ship, 2,100 tons of iron and steel scrap are needed. We manufacture steel plate for those cargo ships. At this rate every three days a cargo ship is lost, which means in bald figures that my com-

pany alone is unable to provide steel plate necessary for the building of 100 cargo ships on a yearly basis. We certainly need iron and steel scrap urgently."

What we in the Industrial Salvage Section ask you to do is nothing new. We ask you to scrutinize the problem thoroughly. Go through your plants and give them a real old-fashioned housecleaning. See if there is some obsolete equipment that can be junked; equipment and stocks that you will never use again. Look in your yards and see if there is dormant scrap, hitherto disregarded; demolish old machinery or, if it is still usable and you don't need it, move it where it can be used. Look into your storerooms and ask yourselves if you are holding back some materials that could be used by the other fellow, who may need them sorely.

## Use It—or Junk It

A short time ago, at the instigation of the section, a large steel mill followed this simple action, and adopted the slogan—"*What we aren't using now, we'll never use—junk it.*" In two months time 125 carloads of iron and steel scrap were turned into their own mills—125 carloads over and above normal movement.

In a letter from a company that has what is recognized as one of the best plant salvage operations in the country—the General Electric Company—is evidence of what can be done by serious application to the problem. The company is doing a real job, one that we regard as a real patriotic contribution to the work of the War Production Board. The text of the letter was as follows:

"You requested me to take up with our factories the matter of dormant scrap. We did this some weeks ago, but it takes a little time to get organized. To date we have uncovered 1,211 tons of dormant scrap, 90 per cent of which is steel and 10 per cent non-ferrous metals. We feel quite certain that by March 13 we will have uncovered a total of 5,915 tons from all our plants. You may be interested to know that we have appointed several men in each factory to inspect every building thoroughly and that we are in process of scrapping some boilers which we have been holding for a number of years. I wish to assure you of our enthusiastic co-operation in this whole matter."

On March 7, we received another letter to the effect that General Electric had not quite made its objective, reporting "slightly under the 5,915 tons originally estimated, 5,850 tons to be exact, but we are continuing the program and will do everything possible to go well over our original objective."

That is what we call real co-operation—"they're on the ball."

Another letter from the President of the Goodyear Tire & Rubber Company, is offered as an indication of what can be done: "I think, however, that you will be pleased to know that upon my return I placed this problem of salvage up to the organization to do a real job within our own plant. We have always tried to keep the situation in hand and scrap everything possible, but in this case I asked for an all-out effort, to stop holding these things at all.

"I am pleased to report to you that the organization has just reported to me that this week they have collected everything and have decided on scrapping out in machinery, old molds, etc., 3,200,000 pounds of metal scrap."

We have received hundreds of reports such as these—reports which have been sent to us voluntarily, describing in detail the movement into flow of tons and tons of materials which otherwise might still be lying around the plants, useless.

## Examples of Home Front Scrappers

The writer is not at liberty to divulge the names of these companies, but would like to give a brief description of a few, as follows:

1. A railroad reported 14,195 tons of iron and steel scrap, 46½ tons of non-ferrous metals and 168 tons of waste paper.

2. A pulley manufacturing company reported that "in January we moved 59,650 pounds of dormant scrap."

3. A chamber of commerce in Texas said: "Following our drive, we turned over, in scrap iron, 6,893 tons in January and 8,243 tons in February."

4. Another report from Texas from a most active association in the area, indicated that for two weeks, 11,000 tons of iron and steel scrap had been collected, and two weeks later that an additional 16,000 tons were moved, with collections "still going strong."

5. Another railroad sent in a complete report, classifying the materials and the companies to which the scrap was sent. Total iron and steel scrap was 3,448 tons; brass, 16¾ tons; copper, 2½ tons; and miscellaneous non-ferrous, 25 tons.

6. A utility company in the South reported: "During the month of February we moved 65 tons of iron and steel scrap; 2½ tons of copper and a small amount of aluminum."

7. A large utility company in the Middle West reported that "from abandoned power houses and dormant scrap we moved 8,400 tons of iron and steel scrap and three tons of copper."

8. A well-known automobile company wrote: "for your record, we are reporting the movement of critically needed materials which we collected

during the month of February—aluminum, 89,784 pounds; brass, 56,507 pounds; iron and steel scrap, 1,148 tons; waste paper, 81 tons; and zinc, $3\frac{1}{2}$ tons.

These cases are cited to give an example of the all-out cooperation we are getting from all kinds of industry. If we can get the whole-hearted understanding and support of each and every business man in the country today, there'll be no shortage, there'll be no question about filling the requirements of the War Production Board and there'll be no question as to who will win the war.

## Operation of the Industrial Salvage Section

At this point some mention should be made of the method of operation of the Industrial Salvage Section. We have approached the solving of this problem in four directions:

1. *Through Industrial Centers:* We have established regional headquarters in 13 different areas, which cover the entire country. These areas have been set up for the most part industrially and not geographically. For example, Philadelphia has a regional office which controls all of Pennsylvania, Maryland, Delaware, West Virginia and part of New Jersey. Each regional director has a staff of field men, who cover all the industrial communities in the region. They set up meetings for the formation of steering and executive committees, which represent every active industry in the particular area. The members of these committees carry through the program to their own particular industry and are personally responsible for putting the salvage program in effect. They receive the constant aid and advice of the Industrial Salvage Section and regional men in the field. To date there are about 425 Industrial Center Organizations in operation. Specially selected salvage men have been appointed in practically every plant to keep the program in motion—not for just a week or month, but from now on.

2. *Through Industries Vertically:* In this group are included industries such as coal, petroleum, public utilities, textile, railroads, etc. On our staff in Washington each of about twelve men directs the program in his own particular industrial field throughout the country, with the aid of the regional men and committeemen of the Industrial Center Organizations.

3. *Through Trade Associations:* Nearly 500 trade associations, through their executives and secretaries have co-operated with the program in every way possible.

4. *Through Governmental Agencies:* The Army and Navy departments have organized a salvage program, the operation of which is similar in character to the program set up by the Industrial Salvage Section. Technical advisors in the section and from the armed forces are called on for

mutual aid and advice, which has resulted in a high degree of efficient operation.

In closing, it should be observed that this is in reality a war of materials and supplies. We have sufficient food and oil available. We have sufficient supplies of needed metals—enough to satisfy the terrific, all-absorbing appetite for planes, guns, ships, etc.—*but we have to find it—dig it out—move it immediately into the flow.* It's our job to do that—it's your job—and it's every American's job.

The writer should like to offer the following as a practical pattern for your salvage operations:

Appoint a salvage director and give him the authority to act. Decide right away what should be re-used, reclaimed or scrapped. Segregate your scrap piles—keep them free from dirt and contamination. Prevent waste by better purchasing, better engineering, better production, packing and shipping.

Find markets for equipment and surplus stocks which some other plant can use. Keep a list of scrap dealers and yards on hand, through which various types of scrap can be speedily turned back into production.

Keep the enthusiasm among the employees high by devising incentives and awards for conservation work.

Establish and keep frequent contact with the Industrial Salvage Section.

Keep up the salvage program *every day—every week—every month.*

# Metallizing as a Method of Water Works Maintenance

*By C. E. Palmer*

ALL who are even remotely concerned with the general maintenance of water works equipment know that corrosion is one of the most destructive agents with which they must contend. In the water works field, safeguarding of metal surfaces is an especially serious problem because of the ever-present combination of moisture and oxygen. Now, in the process called "metallizing," the industry has what seems to be an effective weapon against both corrosion and wear.

Metallizing, or metal spraying, was first tried in Switzerland as early as 1910 and from a not too promising start has evolved into a most practical process of unlimited application in industry today. Its uses and potentialities range all the way from making bronze bookends of the baby's first shoes to the repair or reconstruction of the largest steam turbines and water wheels.

Metallizing is now a highly developed and widely established method of spraying molten metal on metal or on any other properly prepared surface. It has been successfully employed by all branches of industry for many years and merits the particular attention of those concerned with the maintenance of vital plant and shop equipment.

The most commonly used metals for spraying are lead, tin, zinc, babbitt, aluminum, bronzes, brasses, copper, nickel, monel, iron and steels (high, medium and low carbon and stainless). In the process no heat is applied directly to the base material at any stage of the operation, so that there is no warping, distortion, heat strain or stress and no interference with the characteristics of the base material.

The uses of the metallizing process include replacement of metal removed by wear, correction of surface defects, increasing or decreasing of diameters, imparting of desired mechanical, chemical or electrical properties and the application of metal to non-metallic materials. Equipment so treated

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lasts longer, and requires less maintenance and costly shut-downs, because of the fact that, in most instances, coatings of more wear- or corrosion-resistant metals than the original material can be applied.

At the present time, immediate replacement of many worn and damaged parts is virtually impossible. The ever-tightening government control of metals demands that waste be kept to a minimum and that it be eliminated wherever possible. Equipment can be kept in operation by metallizing parts that ordinarily would be discarded, and thereby the process can serve in many ways to reduce waste, save time and materials and keep production at a peak. For this reason the process is an especially vital tool at the moment.

## Experience at Erie Beginning in 1930

The effective use of the process is well illustrated by the experiences of the past few years in Erie, Pa., where it has been adopted extensively in the maintenance work of the Water Department.

In 1930, the Erie Water Department approved the spraying with zinc of all nuts and bolts used in the construction of the West Plant intake pipe—a 72-in. riveted steel line, 8,800 ft. long. A 72-in. built-up steel ball joint which was placed on the lake side of this intake was also metallized with zinc, both inside and out. As this work is entirely submerged below the lake bottom, it has, of course, never been inspected.

In another case, after 18 months of service, the 110,000-gal. steel wash water tank serving the West Filtration Plant showed signs of heavy corrosion and pitting on the interior. As the continual service of this tank was essential to the efficient operation of the plant, the thought of having to take it out of service every 18 to 24 months for painting was quite disturbing. Having previously used metallizing on submarine work, the department decided that it should be given a trial on the inside of this wash water tank where it could be readily inspected and carefully checked at regular intervals.

As this was the first field job undertaken, the work was done by contract which called for the blast cleaning and metallizing with zinc of the interior surfaces only. The tank in question is open at the top, 32 ft. in diameter by 19 ft. 3 in. deep. The method used by the contractor was to sandblast an area just large enough to permit two applications of zinc each day; thus assuring a completed surface which would not be affected by the dust created by subsequent blasting on an adjoining area. The final zinc coating required was 0.006 in. Work was started in May 1934 and completed in about three weeks.

A careful inspection a few weeks ago, after eight years of uninterrupted service, showed no sign whatsoever of coating failure. Had an attempt

been made to protect the surface with paint during this time, there would have been several periods of suspended service totaling at least three weeks. Moreover, the department would have had to look forward to repeating this time-taking procedure at the same regular intervals and the tank would have become more deeply pitted after each operation. Now, however, with no indications of a breakdown in the zinc coating, there is good reason to believe that the metallized surfaces will give many more years of perfect protection.

In making comparisons between metallizing and painting, of course, cost must be a primary consideration. Disregarding interruptions in the service, which in this case was important, a metallized job will cost from two to two and one-half times as much as a good paint job. Nevertheless, it is very apparent that sizeable savings can be made over a period of time. Eight years of service in this particular case has not been sufficient time even to estimate what the full protection period will be.

## Metallizing in the Filtration Plant

Erie's first filtration plant was put into operation in 1914. At that time, twelve filters of the two-bay type were constructed. Bays were 12 ft. 6 in. wide by 28 ft. deep, each containing four steel wash water troughs running the short way of the filter. Four filters having the same plan dimensions and containing the same number of troughs were added in 1925. Maintenance of the steel wash water troughs in this plant, which now consists of sixteen units and a total of 128 troughs, had become a troublesome and costly proposition. In spite of a complete scraping and painting job every two years, during which time all kinds of special primers and paints were tried, the troughs originally installed had become deeply pitted, both inside and out. In fact, where the inside and the outside pitting had taken place in the same spot, holes ranging in size from pinpoint to $\frac{1}{4}$ in. in diameter were found.

Since the condition of these troughs necessitated immediate action and since previous experience had indicated the value of metallizing, it was decided to purchase the necessary equipment and to proceed with the rehabilitation of the troughs by spraying them with zinc.

Proper preparation of the troughs for the metal spraying, while they were in position in the filter, presented a rather difficult problem. As steel grit was to be used for blasting, it was necessary to prevent the grit from flying all over the plant and also to reclaim this grit for further use. This was accomplished by removing enough sand from each half of the filter under treatment to allow the operator to blast and spray the underside of the troughs properly. Heavy tarpaulins were then spread over the entire sand surface and a light framework built over and above the open section of the

filter. This framework was then covered with heavy drop cloths and was so constructed that it could be readily moved from filter to filter as the work progressed. Because of the distance from the blast nozzle, this tent or cover prevented the steel grit from flying out and caused it to drop back into the troughs or onto the tarpaulin where it was later reclaimed, cleaned and then returned to the blast machine.

After ironing out many minor problems such as proper protection of the operators from the steel grit and filtering the gases and oil collected in the compressor from the air supplied to the operator's masks, it was possible to blast and metallize one trough in an eight-hour day. A total of approximately 0.006 in. of zinc was applied in three coats. All holes were filled with the sprayed zinc at the time this coating was applied.

## Cost of Filtration Plant Work

Work on the 128 troughs was started in March 1936 and completed in October of that year. The total surface area of the 128 troughs is 12,432 sq.ft. The total cost of metallizing was $7,962.00. Of this amount, $4,526.63 was charged against labor and included the cost of removing and replacing the sand in each unit as well as that of rough-scraping each trough before grit blasting, which eliminated a considerable amount of dust and thus speeded up the blasting process. About 3,700 lb. of zinc wire were required, but it must be remembered that many holes in the troughs were filled and that the $1\frac{1}{2}$-in. angles riveted to the troughs near the top edge were completely sealed off at both top and bottom edges. About 10,134 cu.ft. of oxygen and 7,237 cu.ft. of acetylene gas were used.

While no estimate was made of the amount of air required, the cost for gasoline, oil, etc. used in a motor-driven two-stage compressor, delivering approximately 160 cu.ft. of air at 100 lb. pressure was about $800 on this job. Of course, the greater part of the compressed air was required for the grit blasting, a relatively small amount being used for the metallizing.

In summing up these figures, it will be found that the cost of metallizing each trough was $62.20. Considering the fact that the troughs would soon have had to be replaced and that not one cent has been spent on their maintenance since 1936, an idea of the savings made possible by metallizing in this particular case is given.

Between December 1936 and May 1937, the 64 steel troughs in the eight filters at the West Side Plant were metallized with 0.006 in. of zinc. These troughs were both wider and deeper than those at the Chestnut Street Plant, having a total surface area of 7,976 sq.ft. Total cost of the job was $4,681. This work was carried out in a manner similar to the Chestnut Street job, but because of experience gained on the first job, the unit cost was somewhat reduced. The Chestnut Street job cost slightly over 64

cents per square foot and the West Side Plant job about 58 cents per square foot.

In speaking of costs, it should be pointed out that many items enter into determining the costs of various metallizing jobs, both of similar and dissimilar natures. For instance, with two tanks of the same size, one located on the ground and the other elevated some 100 ft. above the ground, the cost of handling necessary material in the latter case would, in itself, greatly increase the cost as would the cost of furnishing compressed air for blasting.

Incidentally, it might be well, here, to mention that both blasting and metallizing equipment have been considerably improved since 1936 with a consequent reduction in the cost of all types of metallizing work. With the metal spraying equipment then available, for instance, operations were limited to the application of from 8 to 10 lb. of zinc per hour. With modern equipment, zinc can be applied at the rate of 30 lb. per hour., and, with one type of metal spray gun now available, the density of the spray is automatically controlled.

## Various Applications of Metallizing

Many other uses have been found for the metallizing equipment, acquired by the Erie Water Department, both for corrosion protection and for the rebuilding of worn surfaces.

At the West Filtration Plant the coagulating basins are drained by plug valves in the floor. These valves are operated from the roof of the basin by means of steel rods 22 ft. long. After 4 years of operation, heavy corrosion was noted on these rods, but by the application of zinc, all further corrosion was checked and replacement of the rods made unnecessary.

Similarly, inspection of steel tanks, used in connection with a water softener at the boiler plant, after thirteen years of operation, revealed serious pitting of the interior surfaces, especially at the riveted seams. Calking and exterior welding had been used to stop these leaks, but, after a thorough interior inspection the real cause of the leaks was found to be corrosion of the interior surfaces of the tanks. To correct this trouble at the source, both tanks were blasted on the inside with steel grit and metallized with about 0.008 in. of zinc, particular attention being given to the riveted areas and seams, where additional metal was used.

Since this treatment was completed, over a year and a half ago, all seam leaks have stopped and while no interior inspection has been made to date, it is quite certain that further corrosion has been completely checked. Greatly improved operation and a reduction in the amount of salt used for regeneration has also been noted, but most important is the assurance of

continued service from these tanks which would soon have required replacement if corrosion had not been arrested.

Other applications for the prevention of corrosion included steel ladders in the basin and reservoir, rods exposed to constant moisture or completely submerged, sluice gates and, in fact, all metal surfaces subject to rapid oxidation. The metallizing process also has important values to a water works in the restoration of worn or scored surfaces. Many bronze and steel valve rods which had reached the point of replacement because of wear were restored to service at a cost considerably under replacement charges. By proper selection of the metal to be applied, rebuilt rods give much longer and more satisfactory service than the original rod or stem.

## Application in Pump Maintenance

The impeller shaft of an 8-mgd. motor-driven centrifugal pump on which the bronze sleeve over the steel shaft had been completely worn through by the friction of the packing, was restored to service by undercutting this worn section and refilling it with sprayed stainless steel. The shaft was then ground to a finish and has been in service for several years without any indication of further wear.

Another important job at the Erie plant was the rebuilding of eight outside-packed feed-water pump plungers. These plungers, 6 in. in diameter and 20 in. long, were cast of gray iron, and previously showed considerable wear and noticeable scored and pitted areas after a short period of operation. High-grade and expensive packings were tried to no avail so that it was necessary to repack the glands after each two or three months' service. After about four years' of service, it was also necessary to replace the plungers.

About four years ago the first of these plungers was repaired by undercutting the surface of the plunger $\frac{1}{16}$ in. for the entire length of the stroke. This new surface was then prepared for metal spraying by use of a special knurling tool which roughens the surface to be sprayed and tends to open the pores of the metal, thus assuring a good bond between the prepared surface and the sprayed metal.

With surface prepared the metallizing gun was next fixed to the carriage of the lathe with the nozzle about 6 in. from the work. In this case, the work had to be turned at the approximate number of revolutions that gave a surface speed of 50 surface feet per minute. The carriage speed was then adjusted to about $\frac{1}{16}$ in. per revolution. The metal used for spraying (Metcoloy No. 2 Stainless Steel) was then applied in thin layers by moving the carriage of the lathe back and forth until the new metal had reached a

thickness equal to about 0.020 in. over the original diameter. The rebuilt plunger was then ground smooth and to exact size.

Surprisingly, after nearly four yearsof operation, the plunger shows a smooth glass-like surface without a pit or score mark visible. The chief engineer reports from his record that the original packing is still in the gland and that the gland nuts have never been tightened since the gland was first packed. All of the seven remaining plungers were built up in this manner a few months after the first job had been completed and the same results are being obtained in each case.

Before closing, it should be pointed out that the bond between the metal to be sprayed and the sprayed metal is entirely mechanical in nature, inasmuch as the metal to be sprayed is not heated to a point of fusion. The bond is obtained by forcing the sprayed metal, in a molten state, into the pores and roughened surface of the metal to be sprayed. For this reason, preparation of surface is highly important. In the early days of metallizing, the process received many setbacks because the user failed to consider the importance of proper preparation of surface.

A recent checkup on the various metallizing applications throughout Erie has showed that in every instance the built-up sections of equipment are giving more satisfactory operation and longer service than the original material. Where wearing parts are concerned, this longer service can be attributed to the proper selection of metal and to the fact that sprayed metal has a tendency to absorb and hold lubrication more readily than other metal surfaces.

Though the Erie Water Department was one of the first to adopt metallizing for maintenance work, it is not the only one to have adopted it. Many water storage tanks throughout the country are now protected in this manner, and, as reported by Vance C. Lischer (Jour. A.W.W.A., **34**: 200 (1942)), the St. Louis County Water Co. also makes extensive use of the process, both in protection against corrosion and as a means of rebuilding worn surfaces.

# Conservation of Critical Materials in the Design of the South District Filtration Plant

### *By F. G. Gordon*

WHEN, in the summer of 1941, for the purpose of conserving materials required for defense plants and equipment, the Office of Production Management put into effect a preference rating plan, the South District Filtration Plant of the City of Chicago was about half completed. At that time the breakwater and bulkhead had been finished; the concrete for the east and west substructures had been placed; and the raw-water and filtered-water tunnels, which will serve as connections between the plant and the existing southwest land tunnel system, had been constructed to points north of 75th Street. Part of the piping, gate and cone valves, Venturi meters, sluice gates and floor stands had been purchased and were being erected. The eight low lift pumps had been purchased. Bids had been received for the steel work for the superstructures of the low lift pumping station, filter building and administration building.

The work remaining to be done included the construction of all buildings and the furnishing and erection of the filter equipment, mixers and sludge scrapers, chemical equipment and wash water and miscellaneous pumps. It also included all electrical work, the utility piping outside the plant, tunnel connections, backfilling, grading, landscaping and the final tuning up.

An application was filed on September 11, 1941, for a project priority. When it was pointed out by the then State and Local Governmental Requirements Section that the quantities of critical materials involved were high the application was withdrawn. A new application was filed December 12, 1941, and revised schedules of required critical materials were submitted on January 21, April 29, and May 15, 1942. Each succeeding application and schedule reflected reductions in critical materials. These reductions came as the result of changes in design, substitution of

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non-critical for critical materials and the temporary omission of all items not deemed essential for the operation of the plant.

Up to the present time two priority ratings have been obtained for portions of the work. An A-10 rating was secured for the structural steel for the superstructures of the low lift pumping station, the filter building and the administration building. An A-2 priority was secured for the shore intake work, the tunnel connections and a temporary chlorination plant.

## Architectural Work

In the temporary omission of items from the schedules, the architectural work suffered more heavily than the structural, mechanical or electrical work. The original plans called for fenestration of aluminum sash and glass block. At an early date it was recognized that aluminum sash would become unprocurable, so the plans were changed to permit the substitution of steel sash. After Pearl Harbor the use of steel sash became decidedly questionable. It was finally decided to eliminate all sash from the schedules and, when the buildings were constructed, to board up the openings for the duration. Since a certain quantity of steel frames were required for the glass block, these too were eliminated and these openings also will be boarded up. Enough wood sash can be inserted in the boarded up openings to provide some light for the interiors.

Doors throughout the plant were of metal. All of these were omitted from the schedules and only outside doors and those on the interior which are absolutely essential will be installed. These temporary doors will be of wood and of barn door construction.

All steel stairs throughout the plant were removed from the schedules. Stairs which are essential for operation will be constructed of wood. Passenger elevators have been temporarily omitted. Freight elevators which will serve the chemical building and which are required to handle activated carbon will be retained.

Temporary wood handrailings will be substituted for steel railings. All of the steel laboratory equipment will be omitted and then installed when it becomes obtainable. If the plant is placed in operation before the termination of the war, temporary wood furniture will be constructed.

The architectural plans also call for steel access gates between the filters and the operating aisles. These will be installed later. The omission of these gates and the metal sash and steel doors will make possible the omission of finish hardware.

All plaster work or metal lath will be eliminated until after the war. The postponement of this work will, in turn, effect some savings in the amount of electrical conduit which must be installed at this time. The

office section of the administration building will not be finished for occupancy until later. This will save critical materials required for heating, plumbing, wiring, windows, doors and hardware.

Certain of the toilet rooms will not be equipped at this time. Here again a saving in heating, plumbing and electrical materials will result.

A wood flag pole will be used in place of the steel pole originally contemplated. Window screens can be very readily deferred until a later date.

The plans call for three 200-hp. boilers. Two boilers are required for the maximum heating load. The third boiler will serve as a spare unit. This spare unit will be eliminated for the present. With the temporary elimination of the spare unit, the heating plant will be on a par with a great many other plants in apartments and industries where no reserve is available during extreme cold weather.

The installation of one of the hot water storage tanks will be deferred and one of the two high pressure steam lines serving the west end of the plant will not be installed until later. All heating will be temporarily eliminated in the pipe galleries between the settling basins and in the pipe space between the low lift pump room and the raw water conduits. The screen room will not be heated. In certain locations such as the screen room, the steam and return piping is concealed. At these locations it will be installed. The utility storage room will not be heated at this time.

The original plans called for rubber tile flooring in certain of the offices and laboratories. This will be omitted and asphalt tile used instead.

Through-flashing on copings has undergone a double substitution process. Originally of copper, it was first changed to lead and finally to a heavy roofing felt.

Because of the size of the plant, expansion joints were required throughout the concrete work of the substructures. The concrete work extends in an unbroken line from the port gates at the east end of the plant a distance of 1,496 ft. to the west wall of the filtered water reservoir and from the south wall to the north wall of the same reservoir, a distance of 900 ft. Certain of the expansion joints in the substructure have been carried up through the superstructure buildings. Originally copper was planned for these expansion joints where they occur in roofs. As a substitute, to be replaced at a later date, roofing felt will be used.

At a number of locations throughout the plant, catwalks and valve operating platforms are required. Temporary wood construction will be used here in place of structural steel.

Chlorine cylinders will be stored on a platform at the east side of the chemical building. The architectural design shows a canopy extending the length of the platform. This canopy will be deferred.

### Structural Work

The final design for the chemical building had not been fully determined at the time the contract for the steel work of the three other major buildings was let. It had been planned, however, to make the framework and the bins of the building of steel. With the development of the priority situation, studies were made to determine the reduction in steel which would result from the use of concrete. These studies indicated a material saving in critical materials, so reinforced concrete was used in the final design. As a result of this change the structural steel for the building was decreased from 1,500 tons to 100 tons. The additional reinforcing steel required was 290 tons. The net saving in steel as a result of the change was 1,110 tons. The use of 3,000-psi. concrete is specified for most of the building. Some of the interior columns will be made of 3,750-psi. concrete. Because of the heavier nature of the concrete structure, the re-design required a recheck of the walls and columns of the substructure which supports the superstructure. These were found to be strong enough to take the increased load.

Further conservation of critical materials was effected by omitting all column guards on concrete columns and by deferring the installation of a gantry crane, used to handle chlorine cylinders, until such time as the plant was actually placed in operation.

### Mechanical Work

Studies were made of all mechanical equipment to determine what substitutions, omissions or changes in design would result in a reduction of critical materials. It was found here, as in the architectural work, that certain equipment not essential for plant operation could be eliminated until after the war.

One eliminated item was a 30-in. header designed to distribute waste washwater uniformly across the front of the intake basin. The plant is so arranged that waste washwater from the filters can flow directly to the lake or can pass through settling tanks to the intake basin or the lake. During periods when bathing beaches are in use it may be desirable to convey all waste washwater to the intake basin, thus preventing any complaint about activated carbon on the beaches. With the elimination of the header the waste washwater will be introduced into the intake basin at the corner nearest the settling tanks.

A plant underdrainage system was included in the preliminary drawings. This was designed to collect drainage from sumps in the filter galleries, settling basin galleries and the dry area around the emergency intake shaft. Water from the filter and settling basin gallery sumps can flow, however,

through the bottom level of the settling basin galleries to a cross tunnel below the gallery floors and thence to a sump. The foregoing method of drainage can be used until such time as the need for critical materials no longer exists.

Contracts covering landscaping around the plant and miscellaneous equipment—largely tools for the machine shop—obviously could be postponed. Landscaping included a material amount of cast iron and bronze. This was required for the sprinkler system. Such machine work as might be required after the plant is placed in operation can be done at city shops.

All equipment which might be required in the production of carbon dioxide was omitted. This was deemed not essential to the operation of the plant. This eliminated compressors, motors, pipe, steel plates, wiring and castings.

The screens offered excellent possibilities for the elimination of a great deal of critical material. The screens will consist of 34 units approximately 7 ft. wide and 14 ft. high. They will be installed in vertical guides between concrete piers. Double guides are planned so that a spare screen can be placed behind the regular screen before it is withdrawn for cleaning. The distance from the floor of the screen room to the bottom of the screen guides is about 37 ft. Some 148 lin.ft. of guide are required per screen or about 5,000 lin.ft. of guides for the entire installation. The original plans had contemplated the use of cast-iron guides. Anchor bolts for these guides are in place in the existing concrete. The design was revised to substitute poured-in-place concrete for the cast-iron guides. The existing anchor bolts will provide an excellent anchorage for the concrete. This change will save critical materials and will cost less than the installation first contemplated.

In the original design, the screen frames were to be made of steel. A wood frame which can be used if necessary has been designed. The construction and installation of the screens will be postponed until just before the plant is ready for operation. No substitute for screen wire was devised, but the use of one of the alloys for this material was abandoned.

Suction lines which permit the ready de-watering of each half of the filtered water reservoir will be omitted until materials become available. If necessary it will be possible to de-water either half of the reservoir by careful manipulation of sluice gates at the outlet shaft.

The washwater drain between the plant and the lake will be constructed of reinforced-concrete pipe rather than cast-iron pipe. Because of its size—48 in.—this will, in itself, effect a material saving in critical materials.

Butterfly valves have been substituted for gate valves or sluice gates in a number of locations where the pipe diameter is large; an absolutely tight closure is not required and the head against the gate is small. Most

of these locations are on waste washwater drain lines or on discharge lines from de-watering pumps. The approximate weights of a 24-in. butterfly valve and a standard gate valve meeting A.W.W.A. specifications are 900 and 2,750 lb. respectively.

Materials for gaskets and pipe joints are so specified that critical materials may be eliminated. Paper gaskets have been specified for use on flanged water pipe. Either lead or leadite is permitted for bell and spigot pipe.

The specifications for filter bottoms permit bids on cast-iron pipe underdrains and on alternative types. These other types require materially less critical materials than the cast-iron underdrain system. The 80 filters have an aggregate area of 112,000 sq.ft. It is easy to visualize the possible savings in this one item of plant construction.

From the standpoint of securing a successful substitute, one of the most difficult items proved to be the hard-rubber-lined steel pipe originally specified for chlorine solutions. The chlorine equipment will be located in the chemical building. Chlorine solutions for post-chlorination will be carried from this point to the west end of the plant. Because of the distance involved and the quantities which must be handled, duplicate 4-in. and 5-in. lines are required. The amount of rubber involved is somewhat large. Two substitute materials appear worthy of consideration. One is glass-lined steel pipe and the other, porcelain pipe.

Glass-lined pipe can be obtained in 20-ft. lengths, in sizes up to 5 in. in diameter. The glass lining is carried around the end of the inside of the pipe and across the face of the flange. Rubber gaskets are used.

Porcelain pipe is obtainable in sizes from 1 to 8 in. in diameter and in maximum lengths of 5 ft. The pipe wall is solid porcelain, white-glazed inside and outside, with grooves and gasket surfaces lathe-ground after firing. The wall thickness of a 3-in. pipe is $\frac{3}{4}$ in. and of a 4-in. pipe, $\frac{13}{16}$ inches. "Meehanite" flanges with acid-proof paint are used to bolt together sections of the pipe. Porcelain fittings and valves are also obtainable.

A material saving in copper was effected by the elimination, until after the war, of sampling lines. The original design included lines from all critical points to the control laboratory. Until the installation of the sampling lines, samples will be taken at these points by hand.

## Electrical Work

In the electrical work some conservation of rubber was effected by specifying varnished cambric insulation instead of rubber insulation. The wiring on which this change was made was largely control wiring and

important motor leads. Enameled conduit was substituted for galvanized conduit in certain locations, thus saving the zinc used in galvanizing.

In the first application which was submitted, transformers and incoming cables which will be the property of the power company were included. These were omitted in subsequent applications since they will not be the property of the city, nor will they be installed until the plant is ready for operation.

## Substitutions in Existing Contracts

The priorities obtained for work under construction were not of a high enough order to permit all required materials to be readily secured. Certain substitutions have been made in this work.

The contractor, who was awarded the contract for the structural steel work for the low lift pumping station, filter building and administration building, experienced difficulties in securing a small amount of rolled bronze plates required at expansion joints. A brass foundry was located which agreed to provide cast-bronze plates under the A-10 priority carried by this portion of the work. These would, of course, require planing. Before the order was placed, however, new regulations prevented this solution of the difficulty. Other materials were considered for the expansion joint and it was finally decided to use planed-steel plates which had been impregnated with paraffin. The machining of these plates and the coating with paraffin was estimated to cost more than the difference in cost of the basic materials.

At the front of the intake basin are 34 port openings, 6 ft. by 8 ft. in size. Steel gates with bronze liners were designed to provide control of the water through the ports. Since the bronze required for the 34 gates was an item of some magnitude a substitute material was sought. Wood was considered as having possibilities. The intended application of the wood was described to the Forest Products Laboratory at Madison, Wis., with a request for a recommendation. The laboratory suggested that the two best available woods were oak or maple. If oak were used it was recommended that it be white oak, heartwood, preferably quartered and installed green. Maple, if used, should be dry hard maple sapwood, impregnated with paraffin and then resoaked in water for a week or two before use. It was the judgment of the laboratory that either of these woods would not deteriorate under water. Since the steel gates can be removed readily from their locations, bronze liner strips can be substituted in the future if and when it is found desirable.

In this same contract chromium-plated bolts had been specified. This specification was waived and the substitution of galvanized bolts permitted.

## Reduction in Critical Materials

The reduction (in tons) effected in the major critical materials between September 11, 1941 and May 15, 1942 was as follows:

| MATERIAL | 9-11-41 | 5-15-42 | PERCENTAGE REDUCTION |
|---|---|---|---|
| Structural Steel and Misc. Iron | 5,148 | 3,068 | 40 |
| Reinforcing Steel | 895 | 1,274 | (+42) |
| Cast Iron | 5,744 | 3,186 | 44 |
| Copper | 268 | 128 | 52 |
| Bronze | 91 | 74 | 19 |
| Lead | 237 | 75 | 68 |
| Zinc | 29 | 19 | 34 |
| Rubber | 30 | 10 | 67 |
| Totals | 12,442 | 7,834 | 37 |

The September 11, 1941, estimates are not as accurate as those of May 15, 1942. The plans were not as fully developed and the estimates were not as detailed at the earlier date as they were later. The figures for September 11 are substantially correct, however, and are, if anything, lower than the true figures.

In the last schedule submitted to the War Production Board it was assumed that two years would be required to complete the plant and the critical materials were arranged by periods in the order in which it was expected they would be required. Contracts were so scheduled that requirements for materials were deferred to the latest date possible consistent with the completion of the plant in the scheduled time. The breakdown of the major critical materials (in tons) by periods follows:

| MATERIAL | FIRST PERIOD | SECOND PERIOD | THIRD PERIOD | FOURTH PERIOD | TOTAL |
|---|---|---|---|---|---|
| Structural Steel and Misc. Iron | 1,421 | 859 | 523 | 265 | 3,068 |
| Reinforcing Steel | 828 | 440 | 6 | 0 | 1,274 |
| Cast Iron | 173 | 1,330 | 1,173 | 510 | 3,186 |
| Copper | 10 | 11 | 76 | 31 | 128 |
| Bronze | 4 | 66 | 3 | 1 | 74 |
| Lead | 17 | 41 | 8 | 9 | 75 |
| Zinc | 4 | 1 | 9 | 5 | 19 |
| Rubber | 1 | 5 | 0 | 4 | 10 |
| Totals | 2,458 | 2,753 | 1,798 | 825 | 7,834 |

The following tabulation shows the quantities of materials—now regarded as critical—which were included in all of the contracts which have been awarded up to this time (June 22):

| ITEM | TONS |
|---|---|
| Structural Steel | 5,679 |
| Reinforcing Steel | 22,048 |
| Cast-Iron Pipe and Castings | 2,013 |
| Low Lift Pumps and Motors | 228 |
| Sluice Gates, Lake Port Gates, Valves and Venturi Meters | 1,621 |
| Sheet Copper | 73 |
| Lead | 5 |
| Total | 31,667 |

## Summary

A sincere and earnest effort has been made to reduce to a minimum the quantities of critical materials required for the completion of the South District Filtration Plant. As a result of the revised design and the temporary omissions the required critical materials have been reduced to a tonnage which is less than 25 per cent of the materials previously contracted for. The quantities required for the next year of construction have been cut to 5,200 tons. In asking for a priority to enable the work to be completed under the present revised design it is felt that every effort has been made to conserve critical materials.

# Design of the Chemical Building of the South District Filtration Plant

*By Paul Hansen*

THE most conspicuous characteristic of the chemical building for the new South District Filtration Plant in Chicago is its great size. It is probably the largest chemical building or head house ever designed for any water purification plant. It will be 360 ft. long, 60 ft: wide, 66 ft. high above the water level in the mixing and sedimentation basin. The height above Lake Michigan is 83 ft. The building will stand near the outer end of the area reclaimed from Lake Michigan as a site for the works and thus will be conspicuous when viewed from any direction.

Another striking characteristic of the building is that facilities are to be provided for unusually elaborate chemical treatment. The fundamental reason for this elaborateness is the fact that the plant site, being reclaimed from Lake Michigan, is an expensive one. With an expensive site, it is essential to keep the structures, such as sedimentation basins, within the minimum practicable area. Thus, it is not feasible to rely upon prolonged sedimentation to prepare the water satisfactorily for filtration and, therefore, special chemical treatment must be provided to assure effective flocculation and sedimentation with any condition of the raw water likely to occur, summer or winter.

The height of the chemical building is principally controlled by the desire to use overhead storage in bins for bulk chemicals, with capacity for an ample supply of chemicals to tide over any likely interruptions in the delivery of essential chemicals and with sufficient head room for delivery of the chemicals from the bins to the feed machines without re-elevation.

The original design for the building proper called for structural steel and steel plates for the storage bins. The critical character of steel, however, necessitated re-design using reinforced concrete throughout.

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A paper presented on June 22, 1942, at the Chicago Conference by Paul Hansen, Greeley & Hansen, Engineers, Chicago.

The general location and plan of the chemical building are in large part controlled by the layout adopted for the filter plant as a whole, more particularly the substructures, which latter were largely completed at the time detailed plans for the chemical building were undertaken. The outstanding characteristic of the general plant layout is that the water flows from east to west, passing from the lake into the intake chamber, thence into the raw water pumping station, from the raw water pumping station into distributing conduits and from there into the three units of the filtration plant proper.

Preliminary treatment comprises chemical application, quick mixing, slow mixing and sedimentation. The mixing basins and the sedimentation basins are of the two-story type, with the flows in both stories in the same direction. From the three sedimentation basins the water passes through suitable conduits to four batteries of filters, each battery comprising 20 filters and each filter having a nominal capacity of 4 mgd., thus making a total nominal capacity of 320 mgd. The water from the filters passes into basins underneath the filters and from these, through a filtered water conduit, to the main filtered water storage reservoir at the westerly end of the plant. The water from the filtered water reservoir passes into the existing land tunnel system through new tunnel connections.

## Location of Chemical Building

The logical place for the chemical building is thus at the easterly end of the mixing and sedimentation basins, adjoining the raw water pumping station, and separated from the filter building by the length of the mixing and sedimentation basins, a distance of about 600 ft. While this separation might be objectionable in a small plant, it will not in this case result in any appreciable inconvenience, because each end of the plant requires an operating force of its own in any case. Moreover, between the three units of mixing and sedimentation basins are galleries or passageways amply sheltered from the weather and extending from the east end to the west end of the plant. Thus the general arrangement is satisfactory and convenient.

A railroad siding will be brought in to the plant from the south. The unloading track lies between the raw water pumping station, a low building, and the chemical building. The unloading area will be paved to the level of the railroad tracks so that it may also be used as a lane for the loading and unloading of trucks. Along the entire easterly side of the chemical building is a platform at an elevation convenient for unloading cars and trucks.

The bulk chemicals are to be unloaded by pneumatic conveyor systems, one for each of the three plant units. The liquid chemicals will flow by

gravity, or will be pumped, to receiving tanks from tank cars. The chemicals received in containers, that is in bags and metal drums, will be routed to elevators and delivered to storage rooms on the upper floors. The large storage bins will be divided into compartments for lime, alum or ferric sulfate and ammonium sulfate. Three or four of the compartments in each of the three plant units will be used exclusively for lime and two or three for coagulants, with three in each unit which may be used interchangeably for lime or coagulants, thus allowing ample flexibility in the use of the available storage space.

The bins will have steep sides so that it is expected that the chemicals will feed by gravity to the distributing conveyors leading directly to the weigh hoppers. Some hand work may be necessary to loosen the chemicals when there is a tendency for them to cake. Vibrators are not practicable with reinforced concrete construction. Dust collecting apparatus is connected to all bins.

## Handling of Activated Carbon

The principal chemical to be delivered in containers is activated carbon. Much thought was given to the possibility of storing activated carbon in bulk in bins. It was not felt, however, that there has been sufficient experience with bulk handling of this material, either in shipment or in handling upon delivery, to warrant this practice. Furthermore, there is perhaps greater danger of spontaneous combustion with bulk storage than with bag storage. Another advantage of bag storage is that much space in the building that otherwise would be difficult to utilize effectively is well suited for storage of bags of carbon. A number of rooms are provided on each of three floors for carbon storage; thus, if a fire occurs in one room, it may be controlled without disturbing the others. As it is intended to use carbon dioxide for extinguishing possible fires, the smaller rooms make for economy and effectiveness in the use of the gas. Each carbon storage room will be lined with smooth and impervious tile and the floors will be made smooth and properly drained, so that an entire room may be readily cleaned by hosing.

The carbon will be unloaded and stored on platform skids, 4 ft. by 6 ft. in plan. The skids will be transported by hand-operated hydraulic lift trucks. The freight elevators, one in each unit, are of such size as to handle platforms and trucks conveniently. The skids can be deposited with space between them, to reduce the spread of fire should it occur. Consideration is being given to the possibility of a skid design which will permit the use of steel plate sides as a further precaution against spread of fire.

The bags of carbon will be dumped, in separate dumping rooms, into specially ventilated receiving hoppers, to prevent dust dissemination. The carbon will enter, through appropriate chutes, the weigh hoppers, which are also enclosed and ventilated to prevent escape of dust. The dumping hoppers for activated carbon are an adaptation of a design which has been worked out at the Milwaukee Filtration Plant.

## Chemical Feed Equipment

Lime, coagulants, ammonium sulfate and activated carbon will all be proportioned by dry-feed machines of the gravimetric type. The measured quicklime, in pebble size, will be delivered into slakers and fed as a milk of lime. Measured coagulants and sulfate of ammonia will be dropped into dissolving tanks. Dissolving tanks will be of ample size, provided with stirring mechanisms to insure effective solution of the chemicals. Hot-water connections are included for the lime slakers and coagulant dissolving tanks and all water connections will have rate-of-flow indicators. The carbon-feed machines will discharge into wetting pots equipped with sprays and water injectors.

The dry chemical feed equipment comprises the following, for each of the three plant units: two present, and space for two future, lime slakers and feeders; two present, and space for one future, coagulant feeder; and two ammonium sulfate feeders. All dry feeders have connections to the dust-collecting system.

The chemical solution piping is so arranged that the chemicals from the feed machines of any one of the three plant units may be fed to the chemical mixing conduit of the adjoining unit.

Provision will be made for use of aqua ammonia as well as ammonium sulfate to permit the use of whichever is the cheaper source at any time.

If sodium hexametaphosphate or a similar compound is used for the prevention of the deposition of calcium carbonate or for the correction of corrosion, it will probably be received in metal drums. These can be handled and stored on the same skids used for activated carbon. Provision is to be made for dissolving and feeding metaphosphate in the tanks and feed devices provided primarily for sodium silicate.

At times of weak coagulation of the water, as in winter, it is proposed to use acidified sodium silicate to aid in toughening the coagulant floc. Both the sodium silicate and sulfuric acid are received in liquid form in tank cars. The sodium silicate will be pumped from tank cars into four large storage tanks, each having twice the volume of a tank car, and there diluted with an equal volume of water. The storage tanks for the sulfuric acid will be of steel and located below the level of the railroad track so

that they may receive the strong acid from tank cars by gravity. Small quantities of the acid, as needed, will be pumped into auxiliary acid storage or holding tanks on the top floor of the building.

Preparation of the sodium silicate for use is somewhat complicated and requires a number of tanks. The equipment for each of the three units consists of one acid-holding tank, one acid-weighing tank, one acid-diluting tank, one sodium silicate charging tank and two dilution tanks. The charging tanks will be located above the silicate storage tanks and the sodium silicate will be pumped to them. The quantity for each batch will then be measured from there into the dilution tanks below. It will then be further diluted with water until the concentration of silicon dioxide is about 1.5 per cent. At this stage the dilution tanks will be somewhat less than half full.

The concentrated sulfuric acid will be drawn from the auxiliary storage tanks and weighed in special tanks provided for the purpose. It will then be diluted with about three times its volume of water in the acid dilution tanks. The diluted acid will then be added to the weak silicate solution in the silicate dilution tanks, in which agitators are provided to assure rapid and complete mixing of the chemicals. After a period of aging, varying from 30 min. to 2 hr., the acidified silicate solution will be diluted further so as to contain about 0.6 per cent silicon dioxide. This solution will be fed to the raw water by means of constant level orifice boxes located below the silicate dilution tanks.

## Handling of Chlorine

Chlorine will be delivered to the plant in ton containers, on flat cars. Some consideration was given to receiving chlorine in tank cars holding about 30 tons and then transferring this to large storage containers. It was concluded, however, that the ton containers are more practicable for the present.

The ton containers will be handled by means of a gantry crane from the cars to the loading platform, where they will be stored in the open. As needed, the chlorine cylinders will be removed from storage by means of a mono-rail system and delivered to the chlorine feed room. The cylinders will be placed in pairs within steel tanks, of which there are eight, with space for two more, resting upon scales. The steel tanks will serve both as evaporating tanks and as caustic soda flooding tanks in case of leaks. Warm water for evaporation, when necessary, will be circulated through the tanks, with about one-third of the height of the cylinders

submerged. In case of a bad leak any tank may be quickly filled with caustic soda.

Unlike the feed equipment for dry chemicals and sodium silicate, the chlorine-feed equipment for the entire plant is in one location on the first floor, near the center of the building. There are two chlorine scale rooms, each containing four scales, and a third room for the chlorine feed machines. An emergency ventilating system is provided, with a capacity for effecting one air change per minute in any of the three rooms. Controls for the ventilating equipment are located outside the chlorine rooms.

There is to be a total of fourteen chlorine feed machines, with space for four additional units. Four of the machines will have a capacity of 2,500 lb. of chlorine per day each, six machines, a capacity of 750 lb. per day each, and three, a capacity of 300 lb. per day each. From these machines chlorine may be fed into the raw water either ahead of or after the coagulants, into the mixing basins, into the filtered water conduit and to the outlet of the filtered water reservoir.

Piping is such that groups of chlorine feed machines may be arranged to feed to any of the points just noted, which provides all flexibility of control needed. Further flexibility may be obtained if desired by the introduction of certain additional valves. Plans and specifications are drawn for rubber-lined pipes and valves for conveying the chlorine solution to points of application. In view of the difficulty in obtaining rubber for lining the pipes and valves, it may be necessary to use a substitute (perhaps glass-lined pipes).

At present no provision has been made for the generation of carbon dioxide for back-treating the settled water to remove the mono-carbonates. This equipment was omitted not only because it represents a great deal of critical material, but also because its necessity and economy are not clearly apparent. Sodium hexametaphosphate may serve the purpose, certainly at less installation cost and probably at less operating cost. If, however, treatment with carbon dioxide is later found desirable, space for the necessary equipment is available in the heating plant in the northerly part of the raw water pumping station.

Aqua ammonia will be forced by air pressure from the storage or receiving tanks into daily supply and weighing tanks, where it may be diluted as desired. From the daily weigh tanks, the liquid will be pumped by special pumps to the inlet end of the chemical mixing conduits and into the filtered water conduit. Ammonium sulfate may be applied at the same points.

Because the chemical building contains a large quantity of mechanical equipment, it is deemed desirable to have shops within the building. They

have been arranged in an ell at the south end of the building. Pieces of equipment will be conveyed from and to the shops on hand trucks. The shops will embody space for stock rooms, the usual machine shop equipment and general storage space.

Near the southerly end of the building is to be a control laboratory, solely for the purpose of determining the quantity of chemicals to be used in treating the water. The main laboratory will be located in the administration building at the westerly end of the plant. There will also be an office for a control operator who will give instructions, based on laboratory tests, for the adjustment of mechanical feed equipment. This office will be equipped with various gages for observing the quantity of water going to each of the three units, water level gages and the like, so that the control operator may readily observe the hydraulic conditions throughout the plant. Throughout, careful consideration has been given to convenience of arrangement, adequacy and flexibility.

The architecture of the exterior of the building is of the modernistic type, with stone facing and a relatively liberal use of glass blocks. It is not necessary, however, to depend on daylight, as adequate artificial lighting fixtures have been placed throughout the building to give an abundance of light for observing any operation. The lighting fixtures are largely locally controlled to avoid wasteful use of electric current.

No contracts have yet been awarded for the construction of the chemical building, but bids were called for as of June 29, 1942. The city has made application for an overall priority for the project, which would permit awarding contracts on the concrete framework, the bins and the enclosing walls. In the interest of conserving critical materials several temporary makeshifts are resorted to (see this JOURNAL, p. 1381). Equipment embodying critical material will be placed under contract soon to allow contractors as long as possible for delivery. This is expected to encourage bidding.

The chemical treatment was worked out by John R. Baylis, Engineer of Water Purification, while he was Physical Chemist of the Water Purification Division, of which A. E. Gorman was in charge. The general layout of the building was largely formulated under the general direction of W. W. DeBerard, City Engineer. The final detailed contract drawings for equipment and piping were developed in the office of Greeley and Hansen, Engineers.

# Chemical Treatment Plans for the South District Filtration Plant

*By John R. Baylis*

As NOTED in the paper by Paul Hansen (immediately preceding) the physical equipment of the South District Filtration Plant Chemical Building will be both adequate and flexible, allowing for the adaptation of treatment procedure to that best suited to the condition of the raw water. General plans for treatment procedure have been made on the basis of results obtained from the operation of an experimental plant, but final methods must of course await the dictates of experience.

As now planned, the coagulant will be aluminum sulfate or one of the iron compounds, depending on market prices of the materials. Efficiency of the products for treating the Lake Michigan water at Chicago allows some price differential. This is known and can be taken into consideration. During times when microscopic organisms are abundant, the intention is to use lime to produce a precipitate of calcium carbonate, which, when coagulated, will settle rapidly. During periods in the winter when the coagulation is weak, acid-treated sodium silicate is to be used to strengthen the coagulation.

Activated carbon will be used for taste and odor removal, chlorine for sterilization, ammonia for the maintenance of residual chlorine in the distribution system, and sodium hexametaphosphate or carbon dioxide will be used when lime is added to the water. Table 1 gives the estimated chemical dosages.

Clarification of the lake water at Chicago by processes commonly used in rapid sand filtration plants is simple. The chief filtration difficulty is the rapid clogging of filters and the passage of coagulated matter through the filters. The lake water at the south side intake has an average turbidity slightly less than 10, a peak turbidity near 200, and a minimum turbidity of 1 ppm. The pH of the lake water before treatment remains

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A paper presented on June 22, 1942, at the Chicago Conference by John R. Baylis, Physical Chemist, Bureau of Eng., Dept. of Public Works, Chicago.

fairly constant at 7.9 to 8.1. The alkalinity and the hardness also remain fairly constant at about 120 and 125 ppm., respectively. The water is saturated with calcium carbonate, a factor adding to the ease of treatment.

A filtration plant in which the mixing period is 40 to 60 min., the settling period 5 to 6 hr., and the average filtration rate not more than 1.5 gpm. per sq.ft. would operate about the same as other plants along the lake shore, except that the filter runs likely would be shorter than the runs of most of these plants. More microscopic organisms appear to be present at Chicago than at other places.

The pollution of the lake water on the south side is not greater than that which may be handled by plants of this type. In fact, the pollution is low most of the time. The plant, however, must be prepared to handle the occasional periods of highly polluted water.

TABLE 1

*Estimated Chemical Dosages for South District Filtration Plant*

| CHEMICAL | MONTHS USED EACH YEAR | POUNDS PER MILLION GALLON | | |
|---|---|---|---|---|
| | | Average | Maximum | Minimum |
| Alum or Iron | 12 | 57 | 208 | 33 |
| Lime | 2–6 | 150* | 333 | 0 |
| Activated Carbon | 12 | 58† | 333 | 25 |
| Chlorine | 12 | 5 | 15 | 4 |
| Ammonium Sulfate | 12 | 6.7 | 12 | 5 |
| Sodium Silicate | 1–5 | 50* | 100 | 0 |
| Sulfuric Acid | 1–5 | 5* | 10 | 0 |

* Average for the time used.

† Maximum year; average year will require about ⅔ this amount.

## Occasional High Odors

The lake water is subject to taste and odor caused by microscopic organisms and the waste products of industrial plants. Odor produced by microscopic organisms generally is most pronounced in July, August and September. Tastes and odors caused by industrial pollution are most pronounced in winter when the water is cold. Micro-organisms may cause a strong grassy to fishy odor over a period of from one to two months, whereas the taste and odor periods caused by industrial wastes generally are of much shorter duration, seldom lasting more than three or four days. The intensity of the tastes and odors produced by industrial wastes occasionally is greater than that produced by microscopic organisms, and some of these tastes and odors, while not of high odor threshhold, are very objectionable to the consumers.

## Variation in Coagulation

Very few waters, when coagulated and settled to some definite turbidity, will clog filters at the same rate all of the time. In some places the variation in clogging rate is great. The lake water at Chicago is one in which the clogging rate varies widely. After coagulation and 4 hr. settling, filters with sand of 0.5 mm. effective size may have a clogging rate which varies from less than 0.1 ft. to more than 2.0 ft. per hr. The maximum clogging rate, therefore, may be over 20 times the minimum rate. This variation is too great to provide for satisfactorily with one method of treatment, if prevailing filtration plant design and operation practice are followed.

Part of the reason for the wide variation in clogging rate in filters is the character of the coagulated matter. To determine how much of the variation may be attributed to the character of the suspended matter, experiments were conducted in the Experimental Filtration Plant, covering a period of several years. One filter having 10 sq.ft. of filtering surface and sand of 0.5 mm. effective size was used to filter uncoagulated water in comparison with other filters of the same size handling coagulated and settled water. All other conditions of operation were the same.

The tests showed clearly that the character of the suspended matter had more influence on the clogging rate than anything else. Table 2 gives figures taken from two short periods of operation of two of the filters. In one of the periods the clogging rate was rapid and in the other, slow. The coagulated water passed through a settling basin having about 3.1 hr. retention time. The settling time was 7.7 hr. from February 5 to 7. The filters were operated at a rate of 2 gpm. per sq.ft.

## Danger of Weak Coagulation Passing Filters

Table 3 gives several days results on filters operated according to standard practice during a period of weak coagulation. This period occurred in the winter of 1929–30 and was almost continuous for about 3 months. Filter No. 2 was a rapid sand filter of standard design with 100 sq.ft. of filtering surface. The other filters were one-tenth this size. All had about 24 in. of sand of an effective size of approximately 0.5 mm. and were operated at a rate of 2 gpm. per sq.ft. Volumes of coagulation as given in the table are volumes per million volumes of water. A coagulated turbidity of 1 usually is about 10 to 15 volumes. The table shows that flocculated matter began passing through the filter beds at 1.7 to 4.0 ft. loss of head. Although the time required for the loss of head to increase to 8 ft. varied from 33 to 53 hr., there were periods of only 5 to 16 hr. fol-

lowing filter washes in which no coagulated matter passed through the filters.

## Handling Strong and Weak Coagulation

The filter runs in Table 2 for periods of strong and weak coagulation are selected to show conditions that were confronted in deciding several plant features, such as the treatment to be given the water, the size of sand to use and the maximum rate of filtration. The strong coagulation and short filter runs indicate the desirability of using coarse sand and long periods of settling, or to use a treatment of water that will lessen the clogging rate. The weak coagulation indicates the desirability of using fine

TABLE 2

*Lengths of Filter Runs for Raw and Coagulated Water*

| DATE | RAW WATER TURBIDITY | FILTER RUNS | |
|---|---|---|---|
| | | No Treatment | Coagulated and Settled |
| | *ppm.* | *hr.* | *hr.* |
| 4/17/29 | 12 | 1.6 | 6.6 |
| 4/18/29 | 10 | 1.9 | 3.3 |
| 4/19/29 | 8 | 1.8 | 5.0 |
| 4/20/29 | — | 2.0 | 5.6 |
| 4/22/29 | 10 | 1.5 | 3.9 |
| 4/23/29 | 6 | 2.0 | 3.9 |
| 4/24/29 | 7 | 1.8 | 4.3 |
| 4/25/29 | 10 | 1.7 | 4.1 |
| 4/26/29 | 12 | 1.3 | 5.9 |
| 4/27/29 | 9 | 1.6 | 2.7 |
| Average | 9.3 | 1.7 | 4.5 |
| 12/ 2/29 | 22 | — | — |
| 12/ 4/29 | 20 | 53.7 | 43.7 |
| 12/ 5/29 | 12 | — | — |
| 12/ 6/29 | 10 | — | 43.5 |
| 12/ 7/29 | 10 | 70.0 | — |
| 12/10/29 | 10 | — | — |
| 12/11/29 | 27 | — | 48.7 |
| 12/12/29 | 26 | 49.6 | — |
| 12/13/29 | 18 | — | 39.2 |
| 1/24/30 | 22 | 121.2 | 112.0 |
| 2/ 5/30 | 17 | 114.9 | 47.0 |
| 2/ 6/30 | 18 | 114.9 | — |
| 2/ 7/30 | 17 | — | 84.0 |
| Average | 18.1 | 81.9 | 59.7 |

sand and slow rates of filtration, or, at such times, to use a treatment that will strengthen the coagulation.

Since the tests on the filter handling raw water showed that the suspended matter naturally in the water, and not the treatment, had the greatest influence on the clogging rate, the logical approach to helping increase the lengths of filter runs is to remove as much of the coagulated material as is practical before filtration. During the periods of shortest filter runs,

TABLE 3

*Flocculated Matter Passing Filters**

| DATE | IN SERVICE | TURBIDITY SETTLED WATER GOING TO FILTERS | FILTERS | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | No. 2 | | No. 3 | | No. 4 | | No. 5 | | No. 6 | | No. 7 | | No. 10 | |
| | | | Loss of head | Vol. of floc | Loss of head | Vol. of floc | Loss of head | Vol. of floc | Loss of head | Vol. of floc | Loss of head | Vol. of floc | Loss of head | Vol. of floc | Loss of head | Vol. of floc |
| | *hr.* | *ppm.* | *ft.* | | *ft.* | | *ft.* | | *ft.* | | *ft.* | | *ft.* | | *ft.* | |
| 1/27/39 | 0 | 19.0 | 1.0 | 0.0 | — | — | — | — | — | — | — | — | — | — | — | — |
| | 6 | 19.0 | 1.5 | 0.0 | 1.8 | 1.0 | 1.8 | 0.0 | 1.9 | 0.0 | 1.9 | 0.0 | 1.7 | 0.0 | 1.6 | 0.0 |
| 1/28/30 | 24 | 18.0 | 3.2 | 8.0 | 4.2 | 10.0 | 4.1 | 10.0 | 5.1 | 2.0 | 5.6 | 2.0 | 3.7 | 5.0 | 4.0 | 6.0 |
| | 30 | 18.0 | 4.0 | 15.0 | 5.1 | 20.0 | 5.0 | 24.0 | 6.6 | 2.0 | 7.4 | 6.5 | 4.8 | 5.0 | 5.1 | 35.0 |
| 1/29/30 | 48 | 19.0 | 6.9 | 40.0 | 7.7 | 30.0 | 7.5 | 35.0 | — | — | — | — | 7.5 | 25.0 | 9.6 | 40.0 |
| | 54 | 19.0 | 8.2 | 50.0 | 9.2 | 35.0 | 8.5 | 45.0 | — | — | — | — | 8.7 | 35.0 | — | — |
| Loss of head at which flocculated matter began to pass, *ft.* | | | 1.8 | | 1.7 | | 2.0 | | 3.5 | | 4.0 | | 2.0 | | 1.9 | |
| Length of filter run before flocculated matter began to pass, *hr.* | | | 10 | | 5 | | 10 | | 16 | | 16 | | 10 | | 9 | |
| Time required for loss of head to reach 8 ft. *hr.* | | | 53 | | 49 | | 53 | | 39 | | 33 | | 52 | | 43 | |

* Water treated with aluminum sulfate and then passed through settling basins; 26 min. mixing and 3.1 hr. settling; no settling for filter No. 10.

NOTE: One volume of floc is 1 gal. of compact floc per million gal. of water.

micro-organisms were abundant. When entrapped in the coagulated matter, these organisms greatly reinforce the coagulated material. The desirability of removing a large portion of the suspended matter, including micro-organisms, from the water before it is applied to the filters is therefore evident.

Micro-organisms are of approximately the same specific gravity as the water and their presence in the coagulated matter adds nothing to the

specific gravity of the masses. To produce rapid settling, the specific gravity of the coagulated masses must be increased. In a few filtration plants, clay or other substances at times have been added to the water for this purpose.

Since Lake Michigan water is saturated with calcium carbonate, treatment of the water with lime to produce partial softening seemed the most practical way of producing a rapidly settling coagulation. Experiments showed that the lengths of filter runs could be increased greatly in this manner. Provision therefore has been made for the use of lime in the design of the South District Filtration Plant.

Following the decision to provide for the use of lime in the treatment of the water, full consideration of its economical use in settling the microscopic organisms and in increasing the filter runs was given in the design. The figures indicated that short periods of settling, and use of large amounts of lime at times, gave the greatest economy. The design is not in full accord with the greatest indicated economy, but is in that direction. It was thought best to be on the safe side and await operating experience on the large plant.

If the indicated results are attained, it will be some time before extension of the plant will be required; if not, then the time will not be so long. In these estimates no consideration has been given to the soap saving to the consumers resulting from the softening, which alone should pay for the lime. The extent of the use of lime will depend on conditions of the water, the amount of water being filtered, the size of the sand grains and perhaps other conditions.

Should no attempt be made to improve the quality of the coagulation during periods when the coagulation is weak, the rate of filtration should be lower than that generally regarded as the rated capacity of rapid sand filters, or the sand should be much finer than 0.5 mm. effective size. This is indicated clearly by the results given in Table 3. If finer sand should be used, then the problem of handling the short filter runs would be more serious—so serious that slow rates of filtration obviously would be the better solution, for there is an economical limit to the aid which may be obtained from lime. The desirability of finding some means of strengthening the coagulation during the weak periods, so that fine sand need not be used, was apparent.

Efforts were then made to develop treatments to strengthen the coagulation. The first work along this line was the addition of fibrous material to the water. This was discouraging both because of its cost and its insufficient strengthening effect, although it seemed worth considering if no other means could be found.

The discovery that a certain form of silica in water aids coagulation with aluminum sulfate led to the development of a means of preparing silicate which may be used for this purpose. The silicate is prepared by treating sodium silicate with acid. This has proved a cheap and reliable means of improving coagulation.

## The Silicate Treatment

Provisions for the preparation and use of this specially prepared silicate constitutes the major deviation from conventional treatments in the design of the plant. An account of the development and method of preparing the silicate has already been published.*

With this factor established, the design of the South District Filtration Plant could be studied with the view of developing the most economical plant. The plant as designed is of small size for its capacity. The extreme conditions, which heretofore have limited the capacity of filtration plants, are to be provided for largely by special treatments of the water.

The foremost consideration has been to provide a plant capable of taking care of any extreme condition without having to jeopardize the quality of the water, as so often is the case in plants handling water fluctuating widely in characteristics. The silicate treatment is to be used at times when there is danger that the coagulated matter will pass through the filters. In some winters it may be used only one to two months, but at other times it may be required for four to six months. If the plant starts operation with a low load, such as is expected with a fully metered system, there will not be much use of the treatment until the load is increased. Should the metering program not go forward, the plant then will start operation with a load greater than that generally considered safe for such plants. In this case there may be almost continuous use of the silicate treatment during the winter months and considerable use of lime to lengthen filter runs.

## Use of Large Sized Sand Grains

Experiments with silicate treated water indicate that sand having an effective size of 1.0 mm. will filter the water fully as efficiently as sand of 0.5 mm. without use of the silicate. To be well on the safe side, sand between 0.62 mm. and 0.70 mm. effective size is being specified. The hope is to obtain sand at least 0.65 mm. in size.

The use of sand somewhat coarser than that generally employed will lessen the amount of lime required to lengthen the filter runs during periods

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* BAYLIS, JOHN R. Silicates as Aids to Coagulation. Jour. A.W.W.A., **29**: 1355 (1937).

when microscopic organisms are abundant. It also will lessen the friction loss through the sand layers and enable faster rates of filtration without high initial loss of head on the filters. After development of the silicate treatment and decision to use a coarse sand, the estimated use of lime has been reduced materially and the maximum rate of filtration permissible for the winter months has been increased.

As a result of the development of means of strengthening the coagulation, there is a saving of over 25 per cent in settling time and filtration area regarded as safe design without such means.

The lime and silicate treatments are specially designed to accomplish specific purposes. These treatments could be avoided by having a long period of settling, finer filter sand and a much larger filter area. The very poor quality of water produced by coagulation with aluminum sulfate, settling for 3.1 hr. and filtration at the 2-gpm. rate, as shown in Table 3, indicate that a plant designed for a maximum winter filtration rate of 2 gpm. per sq.ft. would not, with customary treatment, produce satisfactory water all of the time. The results were no better with the use of iron for the coagulant.

# Efficiency Maintenance in Chicago Pumping Stations

*By Frank J. McDonough, Paul Lippert and Julian M. Veggeberg*

THE pumping equipment of the water supply system of the City of Chicago consists of twelve stations which pump an average of about 1,000 mgd., with summer peak demands reaching a 1,600-mgd. rate. The various stations have steam-engine-driven, steam-turbine-driven and electric-motor-driven pumps. Some of the stations have a combination of engine- and turbine-driven units; others a combination of engine- and motor-driven units.

Pump capacities range from as low as 15 mgd. to 80 mgd. normal capacity on the most recent steam-turbine-driven units which are operated to almost a 100-mgd. rate at peak demand. The rated total heads range from 125 to 236 ft.

The area supplied consists of 212 sq.mi. within city limits and upwards of 100 sq.mi. in the suburban areas adjoining the city, or a total of about 312 sq.mi. The distribution system within city limits contains 3,851 mi. of piping, from 3 to 54 in. in diameter, with 412,000 connected services and 41,400 fire hydrants.

From the comparatively enormous amount of equipment necessary to maintain a water supply system of this size, it is easy to see that it requires considerable expert attention, not only for periodic tests and repairs to keep the equipment in an acceptable and efficient operating condition, but also to supervise, formulate rules of operation and maintain the necessary discipline required in such an extensive organization. The duties of every employee in the office or at the plants are definitely outlined and, except in extraordinary cases, are strictly followed.

For about seventeen years the city has maintained a group of engineers, known as the Section of Pumping Station Efficiency, to make regular periodic tests on all pumping station equipment listed as ready for service,

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A paper presented on June 22, 1942, at the Chicago Conference by Frank J. McDonough, Asst. Mech. Engr., Div. of Pumping Station Operation; Paul Lippert, Engr. of Pumping Station Efficiency; and Julian M. Veggeberg, Sr. Designer, Filtration Design Sec.; all under the Dept. of Public Works, Chicago.

as well as to make all "Official Acceptance Tests" of new equipment. The scope of this periodic testing is wide, including pumps, motors, generators, steam turbines, steam engines (all triple-expansion), all steam generating equipment and boiler auxiliaries. Chlorine apparatus is tested in connection with the Water Safety Control Section of the Division of Water Purification.

The entire supply system of water tunnels, with the exception of the recent Chicago Avenue system, has been carefully tested for friction losses. At times as much as twenty miles of tunnel has been under observation, such tests requiring the services of more than twenty skilled observers to obtain necessary data.

## Study of Surges in Tunnels

Where motor- or steam-turbine-driven pumping equipment is used there is always the probability of a complete load rejection caused by either an interruption of electrical service or the "kicking off" of the overspeed governor of the steam turbines. When there are several stations supplied from a single tunnel, great, and at times serious, hydraulic disturbances will obtain. It is of prime importance to have complete and accurate knowledge of the extreme limits of such disturbances, so that adequate spillways or other types of safety reliefs can be installed at correct elevations to safeguard the stations and their equipment. It is known, for example, that when the Chicago Avenue tunnel system is up to a load of about 700 mgd., a complete rejection at the Cermak Pumping Station of, say, 225 mgd. will produce a surge wave of nearly 40 ft. in the Cermak station shaft. It is, therefore, important that some adequate relief be provided to reduce this wave to a safe limit, thus reducing the violent disturbance which might seriously affect the operation of the Chicago Avenue, 22nd Street, Springfield Avenue and Central Park Avenue Pumping Stations, all of which are supplied entirely from this tunnel system.

Since the tunnel systems are entirely too complex for any known analytical treatment, either the model method, using the theory of kinematic similitude, or a very novel graphical method developed by Julian M. Veggeberg is used in the determination of these surge effects. For some types of water tunnel problems involving special information, salt tests are made, which, if correctly done, will give accuracies approaching that of Venturi meters. This is known to be true from tests that were verified by Venturi meter readings. It is, of course, apparent that tunnel tests are, at times, large and costly, but when certain data are required, such tests are the only satisfactory means of obtaining the information.

Several years ago the Section of Pumping Station Efficiency initiated an entirely new procedure for the so-called boiler trial method. This new

method separates the stoker from the boiler, since it is viewed as a fuel-burning device only, and is really not related in any manner to the boiler.

When a stoker will burn a specified fuel at the desired rates satisfactorily, maintaining a fixed carbon dioxide percentage without an excess of combustible in the refuse, and doing all of this under forced draft, furnace pressures and chimney draft as specified, the stoker must be viewed as meeting the requirements set up regardless of the boiler performance. The boiler is viewed as a heat-absorbing device and must, when supplied with sufficient heat, deliver the desired or required weight of steam at a given state point. From uptake temperatures and a heat balance, the boiler efficiency can be satisfactorily obtained. This method of boiler and stoker testing has proved very satisfactory in practice and eliminates all controversies heretofore experienced.

## Pump Tests

All pump tests are made in conformity with accepted codes, the motor-driven tests being quite simple, necessitating only wattmeter, suction and discharge pressure readings and the volume flow and the rate and time of test period. These tests are taken at from four to five different rates in order to establish a sufficient number of points to draw accurate capacity-head, efficiency and horsepower curves.

The steam-turbine-driven pumps require a far more elaborate method, as shown on the typical form (Fig. 1), which demonstrate the fact that all important items are measured or computed from instrument data. Usually, before a steam-turbine test is made, a careful condenser-leakage test run is made, since it is practically impossible to arrive at acceptable results when the leakage is high. The condensate or steam consumption of the unit is also carefully weighed, since this weight and the state point of the steam, i.e., pressure and superheats, are the vital required quantities for accurate test results.

Recently at one of the stations a new boiler installation brought about a more or less complex system of steam supply, which unfortunately caused wide variations in superheats. These variations necessitated extrapolation for correction coefficients and caused some apparent inconsistent results in the water rate of the turbine. While not of great importance, since the condition is only temporary, this experience does show that conditions extending beyond certain limits are very likely to lead to erroneous results.

Throughout the operating life of all motor or turbine units a continuous performance history is kept in several forms.

The test results on motor-driven units are shown by graphs which, in addition to capacity head, dynamic suction, electrical and water horse-

_______________ PUMPING STATION

TESTS ON

DE LAVAL STEAM-TURBINE-DRIVEN CENTRIFUGAL PUMP NO.

| | | OPERATING POINT | PREVIOUS TEST | SPECIFIED LOAD | PREVIOUS TEST | | |
|---|---|---|---|---|---|---|---|
| 1 | Date | | | | | | |
| 2 | Duration - hr. | | | | | | |
| 3 | Speed - rpm. | | | | | | |
| 4 | Pumpage by Venturi Manometer - mgd. | | | | | | |
| 5 | Total Test Head - ft. | | | | | | |
| 6 | Water Horsepower Calculated | | | | | | |
| 7 | Total Dry Steam Used per hr. | | | | | | |
| 8 | Total Steam Consumption per Water hp.-hr. | | | | | | |
| 9 | Duty - mil.ft.-lb. per 1,000 lb. of Steam | | | | | | |
| 10 | Duty - Corrected by De Laval Curves | | | | | | |
| 11 | Throttle Steam Pressure - Gage Corrected | | | | | | |
| 12 | Temperature of Throttle Steam | | | | | | |
| 13 | Superheat of Throttle Steam | | | | | | |
| 14 | Barometer (Corrected to 58°F.) - in. Hg | | | | | | |
| 15 | Vacuum (Corrected to 58°F.) - in. Hg | | | | | | |
| 16 | Back-Pressure - abs. lb. | | | | | | |
| 17 | Suction of Main Pump at C.L. Pump - ft. | | | | | | |
| 18 | Discharge Pressure at C.L. Pump - ft. | | | | | | |
| 19 | Correction for Increased Velocity Head - ft. | | | | | | |
| 20 | Condenser Leakage per hr. - lb. | | | | | | |
| 21 | Temperature of Water at Condenser Inlet | | | | | | |
| 22 | Temperature of Water at Condenser Outlet | | | | | | |
| 23 | Temperature of Condensate | | | | | | |
| 24 | Nozzles Open | | | | | | |
| 25 | Lb. Steam per Water hp.-hr. (Corr. by De Laval Curves) | | | | | | |

NOTE - Exhaust from Air Pump Discharged to in all Above Tests

| SPECIFIED | | | |
|---|---|---|---|
| Pumpage | | | |
| Total Head | | | |
| RPM. | | | |
| Duty | | | |
| Lb. of Steam per Water hp.-hr. | | | |
| Steam Pressure Gage | | | |
| Superheat | | | |
| Water hp. | | | |

REMARKS

Hours of Operation

Hours of Operation

Section of Pumping Station Efficiency

FIG. 1. Typical Form for Steam-Turbine-Driven Pump Test Record

power, also give efficiencies, a statement of total operating hours from installation to date of test, the time interval between tests and any repairs or replacements made during this time interval. These graphs (Fig. 2) give a complete history of the unit for a particular period and have been found very useful.

The form used for steam-turbine-driven units (Fig. 1) also has a sufficient number of columns to show several and comparative tests together with the specified load, total hours of operation and time between tests.

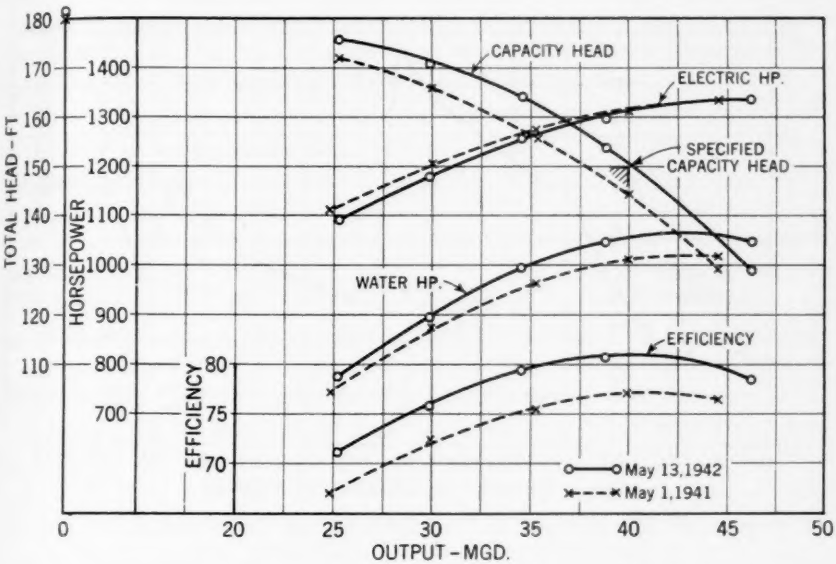


FIG. 2. Test Data on Motor-Driven Pump—Hours of Operation Since Previous Test, 3,821; Hours of Operation Since Installation, 42,534; Repairs, New Sealing Ring on Impeller

When necessary, notes regarding repairs and replacements can be and are given on this sheet.

For a complete record of variations in efficiencies, operating hours and periods of repairs and replacements, another graph (Fig. 3) is made, concentrating on one sheet a complete history of the unit's performance and indicating repairs and replacements made during the period covered. Finally, a complete detailed sheet (Fig. 4) showing all important items is kept. The prime purpose of this record is to concentrate all available information on a single sheet, where possible, thus providing a convenient tabulation for study and comparison of the unit's performance throughout its operating life.

The operation and maintenance of the water supply pumping stations and the intake cribs in Lake Michigan, including the tunnels from the intakes to the various stations, are under the supervision of the Operating Division of the Bureau of Engineering. Each pumping station is in charge of a Chief Operating Engineer and, as all of the stations are operated on a continuous basis, they are supervised by Assistant Chief Operating Engineers who work in eight-hour shifts, being relieved for one period once each week.

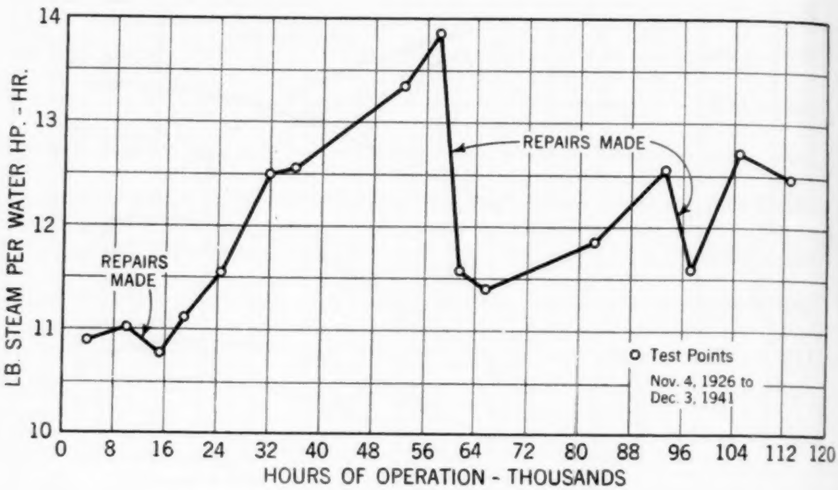


Fig. 3. Pump Performance Efficiency Data Curve

Depending on the size of the station and the service which it is required to perform, each station is provided with the necessary number of Operating Engineers Group C, stationary firemen, chlorine attendants and station electricians. The force on duty at all times is sufficient to place the plant in full operation at any time of the night or day. As the city operates its stations on an inter-connected water main discharge system, any load that may be dropped at a station may be picked up by the nearest station or combination of stations.

## Maintenance and Repair

For maintenance and repair of the equipment, each station is provided with the services of machinists and steam fitters. A small shop with necessary tools is provided for each plant. For repairs to impellers and other equipment up to 50 in. in diameter and for shaft mountings of 12 ft. in length, the city has a well equipped lathe available in its Construction

Division Shop. Detailed drawings of the various sizes and kinds of impellers with their rings, sleeves, shafts, bearings, etc., are available for use by the mechanics engaged in their repair, and the drawings are always referred to for correct sizes when any part of the equipment is being rebuilt or repaired. Patterns for castings of the various parts of centrifugal pumps are also available, stored in the City Pattern Loft ready for use, at any time they may be required.

The repairs and overhauling of the water pumping equipment must be done at the various stations in that part of the year following the cold weather of winter and the hot weather of the summer. These repairs are also arranged so that taking a unit out of service will not jeopardize the water supply in the territory which the station supplies.

The results of the acceptance or the original tests made on equipment at the time it is first placed in service are used by the Operating Division engineers as a basis of comparison with the results of all tests made later on the same unit, after it has been in service for some period or following overhaul or repairs. By making such comparisons, it is possible to ascertain whether the overhauling has been successful in re-establishing the original efficiency of the unit or to what extent the service performed by the unit has caused a loss in efficiency which has not been re-established. A study of the results will usually disclose that further repairs must be made to bring the unit up to its original efficiency.

Experience in making repairs and overhauling the large capacity pumping units indicates that the mechanics and engineers are more careful with their work and strive to put all parts undergoing repairs in the best possible condition, knowing that the results of their work will show up in the service test on the unit after the job is completed.

## Cost Accounting System

Daily reports of the cost of labor and material used for repairs and maintenance at all pumping stations are made and tabulated on a cost basis against the various units of the station. The cost is subdivided by code letters representing various parts of the unit, and tabulated in such a manner that the cost of maintaining the various parts of the unit can readily be determined and studied to find out what part of the unit shows excessive cost of maintenance. By this system of cost accounting it is possible to compare the maintenance and repair cost of the various units, regardless of the station in which they are in service.

A monthly report of the costs is compiled. The costs of maintenance and repairs for all stations are tabulated on one sheet and from this all the operating engineers of the stations can see how they stand as compared with any other station in the system. In addition, a monthly detailed

# CENTRAL PARK AVE. PUMPING STATION

## PUMP NO. 3

RECORD OF REPAIRS AND RESULTS OF ALL TESTS SINCE INSTALLATION

MAKE AND TYPE OF PUMP – DE LAVAL STEAM-TURBINE-DRIVEN CENTRIFUGAL

GOVERNMENT BRONZE IMPELLER

### SPECIFIED CONDITIONS

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Pumpage – mgd. | 50 | 60 | 70 | Lb. Steam per Water hp.-hr. | 11.51 | 11.01 | 11.13 |
| Total Head – ft. | 150 | 150 | 125 | Steam Pressure | 175 | 175 | 175 |
| Water hp. | 1315 | 1578 | 1534 | Deg. Superheat | 150 | 150 | 150 |
| Duty – mil. ft.-lb. per 1,000 lb. Steam | 171.9 | 179.8 | 177.8 | Lb. Steam per hr. | 15,137 | 17,371 | 17,075 |
| Rpm. | | | | | | | |

| STARTED OPERATION AS NEW PUMP 4-22-26 | | | | | | | | | CORRECTED BY DE LAVAL CURVES | | | | HOURS OF OPERATION SINCE PREVIOUS TEST OR REPAIR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DATE OF TEST | MGD. | RPM. | HEAD IN FEET | | | STEAM | SUPER- | W. HP. | LB. STEAM PER W.HP. | DUTY | | | |
| | | | SUCT. | DISC. | †TOTAL | PRESS. | HEAT | | | 50 | 60 | 70 | |
| •11-5-26 | 50.1 | 484 | 17.89 | 130.22 | 148.96 | 174.3 | 123.6 | 1308 | 11.44 | 173.0 | BEFORE ACCEPTANCE TEST | | 3,884 |
| •11-4-26 | 61.28 | 501 | 20.59 | 127.9 | 149.76 | 173.9 | 127.1 | 1609 | 10.89 | | 181.8 | | |
| •11-3-26 | 70.44 | 486 | 19.36 | 104.79 | 125.83 | 176.0 | 123.6 | 1555 | 10.73 | | | 184.4 | |
| 4-8-27 | 50.44 | 440 | 14.69 | 104.41 | 119.97 | 164.1 | 123.2 | 1062 | 11.12 | 178.0 | | | |
| 4-8-27 | 58.3 | 462 | 17.32 | 109.05 | 127.51 | 162.3 | 134.7 | 1302 | 10.63 | | 186.2 | | |
| 4-8-27 | 70.8 | 483 | 17.14 | 106.81 | 125.65 | 162.6 | 132.9 | 1560 | 10.38 | | | 190.8 | |
| 4-11-27 | 50.4 | 447 | 16.4 | 107.8 | 125.08 | 177.0 | 120.8 | 1109 | 11.24 | 176.1 | | | |
| 4-11-27 | 60.55 | 475 | 19.75 | 112.4 | 133.4 | 173.4 | 129.0 | 1460 | 10.61 | | 186.6 | | |
| 4-11-27 | 72.44 | 494 | 19.0 | 106.6 | 127.39 | 176.1 | 125.2 | 1619 | 10.92 | | | 181.2 | 3,545 |
| REPAIRS – EXHAUST END TURBINE BEARING REPAIRED – OUT SERVICE 6-21-27 – IN SERVICE 6-22-27 | | | | | | | | | | | | | 1,726 |
| 8- 3-27 | 49.28 | 432 | 17.20 | 98.6 | 116.63 | 163.3 | 124.9 | 1007 | 11.75 | 168.5 | | | |
| 8- 2-27 | 60.08 | 467 | 20.93 | 105.5 | 127.66 | 158.3 | 135.6 | 1344 | 11.03 | | 179.5 | | |
| 8- 2-27 | 70.1 | 494 | 20.93 | 106.9 | 129.51 | 157.7 | 136.2 | 1590 | 11.33 | | | 174.6 | 926 |
| REPAIRS – STEAM CASING REMOVED AND TURBINE CLEANED. CARBON RINGS REPLACED. GEARS AND BEARINGS CLEANED – OUT SERVICE 1-15-28 – IN SERVICE 2-2-28 | | | | | | | | | | | | | 3,273 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4-20-28 | 50.5 | 451 | 15.03 | 109.69 | 125.59 | 160.0 | 145.8 | 1112 | 11.45 | 172.9 | | | |
| 4-19-28 | 60.86 | 482 | 17.32 | 117.49 | 136.07 | 157.5 | 160.0 | 1451 | 10.77 | | 183.7 | | 1,626 |
| 10-29-28 | 50.8 | 451 | 13.81 | 110.81 | 125.5 | 161.3 | 114.4 | 1117 | 11.65 | 169.9 | | | |
| 10-29-28 | 60.0 | 473 | 17.38 | 112.62 | 131.23 | 158.4 | 120.1 | 1380 | 11.12 | | 178.0 | | 3,753 |
| REPAIRS — NEW CARBON RINGS — BEARINGS SCRAPED IN — OUT SERVICE 2-21-29 — IN SERVICE 5-12-29 | | | | | | | | | | | | | 2,570 |
| 10- 8-29 | 48.6 | 461 | 13.22 | 117.95 | 131.97 | 159.5 | 134.6 | 1125 | 12.27 | 161.3 | | | |
| 10- 7-29 | 59.74 | 485 | 16.46 | 123.15 | 140.82 | 158.0 | 143.3 | 1475 | 11.55 | | 171.4 | | |
| 10- 7-29 | 66.0 | 501 | 18.6 | 123.55 | 143.63 | 156.8 | 143.9 | 1661 | 11.38 | | | 174.0 | 3,375 |
| 10-10-30 | 50.57 | 460 | 16.02 | 113.37 | 130.26 | 160.0 | 125.4 | 1156 | 12.88 | 153.6 | | | |
| 10- 8-30 | 58.4 | 476 | 16.42 | 117.26 | 134.84 | 159.0 | 126.1 | 1380 | 12.47 | | 158.8 | | |
| 10- 9-30 | 69.27 | 496 | 17.23 | 114.37 | 133.23 | 156.2 | 126.2 | 1618 | 12.33 | | | 160.5 | 7,196 |
| 5- 3-32 | 49.42 | 458 | 18.0 | 109.25 | 128.08 | 158.4 | 116.7 | 1110 | 13.2 | 150.0 | | | |
| 5- 2-32 | 63.69 | 487 | 20.48 | 112.85 | 134.71 | 157.2 | 113.4 | 1505 | 12.55 | | 157.8 | | |
| 5- 2-32 | 70.24 | 505 | 20.14 | 109.95 | 131.77 | 154.5 | 113.6 | 1623 | 13.0 | | | 152.2 | 11,946 |
| 5-22-33 | 49.05 | 439 | 15.16 | 99.46 | 115.44 | 159.0 | 121.6 | 992 | 13.82 | 143.3 | | | |
| 5-22-33 | 60.22 | 465 | 19.77 | 100.36 | 121.37 | 158.2 | 121.3 | 1280 | 13.33 | | 148.5 | | |
| 5-22-33 | 70.7 | 486 | 18.05 | 98.86 | 118.61 | 155.2 | 131.7 | 1470 | 13.46 | | | 147.1 | 8,360 |
| 1-24-34 | 59.8 | 508 | 15.28 | 133.5 | 150.0 | 155.7 | 125.0 | 1574 | 13.85 | | 142.8 | | 5,698 |
| TURBINE REPAIRS — NEW #2 - #3 WHEEL AND DIAPHRAGM PUMP — SEALING RINGS, CASE RINGS, SHAFT SLEEVES, PUMP BEARING, NEW BABBITT | | | | | | | | | | | | | 1,790 |
| 9- 7-34 | 60.9 | 500 | 17.6 | 134.8 | 153.6 | 157.6 | 136.6 | 1639 | 11.57 | | 171.1 | | 1,740 |
| 9- 7-34 | 69.9 | 482 | 20.0 | 103.6 | 125.3 | 159.8 | 131.9 | 1535 | 11.2 | | | 177.1 | |
| 3-14-35 | 63.1 | 512 | 19.13 | 133.3 | 153.78 | 154.0 | 131.7 | 1702 | 11.41 | | | 173.5 | 3,948 |
| CONDENSER RETUBED | | | | | | | | | | | | | |
| 5-10-37 | 61.5 | 495 | 2.76 | 141.6 | 145.6 | 155.9 | 82.5 | 1571 | 11.84 | | 167.2 | | 16,584 |
| 5-10-37 | 71.3 | 484 | 3.76 | 119.8 | 125.3 | 154.8 | 88.8 | 1567 | 11.31 | | 175.0 | | |
| 11- 4-38 | 67.9 | 490 | 3.9 | 127.4 | 132.9 | 156.5 | 89.2 | 1582 | 12.11 | | 163.4 | | 11,163 |
| 11- 4-38 | 62.4 | 507 | 3.1 | 146.8 | 151.3 | 155.5 | 88.6 | 1657 | 12.52 | | 149.5 | | |
| REPAIRS — 3 LOW PRESSURE DIAPHRAGMS SENT TO TRENTON FOR REPAIRS — MAIN PUMP SLEEVES AND CASE RINGS TURNED UP — RENEWED CIRCULATING PUMP SHAFT SLEEVES, WEARING RINGS, CASE RINGS — IMPELLER BALANCED AT G.E. SHOP. | | | | | | | | | | | | | |

• NOTE - Acceptance Tests - Exhaust from air pump discharged to condenser. On all other tests this exhaust discharged to heater.

' NOTE - Total head includes correction for increased velocity in discharge pipe.

FIG. 4. Complete History of Pump as Shown on Single Record Sheet

report of operation and cost is compiled, showing the figures for each station and the total for all stations in one report. This report, with copies of all tests made during the month, is sent to the Chief Operating Engineer of each station for his information.

Considering that it costs the city approximately **$360,000** a year to maintain and repair its water supply pumping stations, and that the cost of electric power and coal consumed for operation is about **$1,000,000** per year, it is imperative for economy and reliable service that the equipment be kept in its most efficient operating condition and, as far as it is possible, that costs be prevented from rising or service, from being interfered with due to neglect in maintaining the equipment. All of the employees of the Operating Division and the Section of Pumping Station Efficiency are striving to accomplish this purpose.

## Erratum

In "Perforated-Pipe Underdrains for Rapid Sand Filters" by Edwin A. Schmitt and Philip O. Macqueen, Jour. A.W.W.A., **34:** 857 (1942), are published certain figures for San Diego which were given incorrectly to the authors. Paul F. Bovard, Manager of the California Filter Co., has supplied the following information:

"The filter units are 18 ft. od. and have an effective sand area of 240.53 sq. ft.

"The most serious error is in the perforation data where the diameter of holes is given as $\frac{1}{8}$ in. and should be $\frac{1}{4}$ in. The tapping was $\frac{1}{8}$-in. pipe tap, into which were screwed $\frac{1}{4}$-in. ferrules, or eyelets, of brass. As each unit contains 1,648 holes, $\frac{1}{4}$ in. in diameter, the effective area is 0.561 sq. ft.

"This gives the value, as tabulated on p. 869, under San Diego, of 0.0023, as the ratio of the area of perforation to the net sand area.

"Therefore, correcting the data on p. 869, the effective area of all the laterals is 1.046 sq.ft., there being 48 laterals 2 in. in size."

# Effect of Sodium Hexametaphosphate on the Solution of Lead

*By Edward W. Moore and Fred E. Smith*

At a joint meeting of the New England Health Institute, the New England Water Works Association and the New England Sewage Works Association, held in April 1941, Dr. L. T. Fairhall of the National Institute of Health questioned the use of sodium hexametaphosphate for corrosion control in systems containing lead pipe. Dr. Fairhall had found that concentrations of metaphosphate of about 1,000 ppm. produced large increases in the solubilities of some of the common lead salts. Ruchhoft and Kachmar (1) subsequently confirmed Fairhall's experiments, but allayed much of the anxiety that had been produced with respect to the use of metaphosphate by showing that in quantities of 1 to 10 ppm., the metaphosphate actually decreased the solubilities of lead salts.

Hatch (2) published results on the effect of metaphosphate on the corrosion of lead wool, in which he showed that the solution of lead from the cleaned metal was markedly inhibited in waters of pH 6.0 or below. At and above pH 7.0, his results gave some indication that the metaphosphate slightly increased the solution of lead.

It has seemed to the writers that the gravest question with respect to the introduction of metaphosphate into water systems containing lead pipe is that of the effect of this chemical on the deposits of lead salts previously formed in the pipe. Metaphosphate has been known to cause rapid removal of pipe deposits in some systems in which it has been introduced, and such removal would be particularly dangerous if the deposits contained a high percentage of lead. It has also seemed desirable to provide independent confirmation of the results of the investigators cited above, since the problem is significant to public health.

In all experiments presented in this paper, the lead concentrations were determined by the dithizone method as described in *Standard Methods* (3). The only modification adopted consisted of the use of a Cenco-Sheard

A contribution by Edward W. Moore, Assoc. Prof. of San. Chemistry, Harvard Graduate School of Eng., Cambridge, Mass., and Fred E. Smith, Chemist, Cambridge Filtration Plant, Cambridge, Mass.

Photelometer for reading the colors. The experience of the authors confirms the statement of Ruchhoft and Kachmar that the method gives results sufficiently reliable for the purpose.

## Preliminary Experiments

Experiments were performed by the senior author on the effect of metaphosphate in small quantities on the solubilities of basic lead carbonate, litharge and lead sulfate. The results of these experiments were so irregular as to cause them to be regarded as inconclusive. Those of Ruchhoft and Kachmar do not seem to be open to this objection.

A few experiments also were made on old lead or lead-lined pipes which had been removed from the Boston and Cambridge systems. These were prepared by filling the pipes with water containing varying amounts of metaphosphate and allowing them to stand overnight. The results also were irregular and were open to the additional objection that the character of the deposits in the pipes may have been considerably modified by long periods of drying in the open air.

## Tests on Lead Wool

The preliminary experiments led the authors to conclude that steady-flow tests over fairly long periods of time offered the best means of obtaining results of value. Consequently an apparatus analogous to that of Hatch was constructed. This apparatus is shown diagrammatically in Fig. 1. The only significant difference between it and the apparatus of Hatch is that a tube of "Micromet," a slowly dissolving form of metaphosphate, was substituted for the liquid metaphosphate feed of Hatch's equipment. Given a constant rate of flow through the apparatus, the "Micromet" produced a fairly uniform metaphosphate dose. In these experiments, the quantity of "Micromet" and rate of flow were such that a dose of about 3 ppm. of metaphosphate was obtained. The quantity of lead used in each experiment was 200 g. and the rate of flow of water, 200 ml. per min. From these figures, it is estimated that the metaphosphate dose per unit of lead surface was approximately one-third that used by Hatch.

Some initial difficulty was experienced in the use of "Micromet." The product obtained had a small amount of impurity, either lead or some other metal which responded as lead to the dithizone test. Practically all of this metal passed from the "Micromet" into the water in the first two days of the experiment and corrections had to be made in the form of blanks obtained by running the same water at the same rate through a separate tube of "Micromet." After this contaminant had been leached out, no further blanks were necessary.

The preparation of the lead wool for these tests deserves some mention, since it differs from the technique used by Hatch. In the authors' experiments, the lead wool was washed consecutively with chloroform, soap and water, water, sodium hydroxide and water. It was then dried at 103°C. This treatment developed a grayish coating on the surface of the lead wool, presumably some form of oxide or hydrate. In this condition the lead wool was possibly more comparable to the interior of a used lead pipe than to a fresh surface of metallic lead.

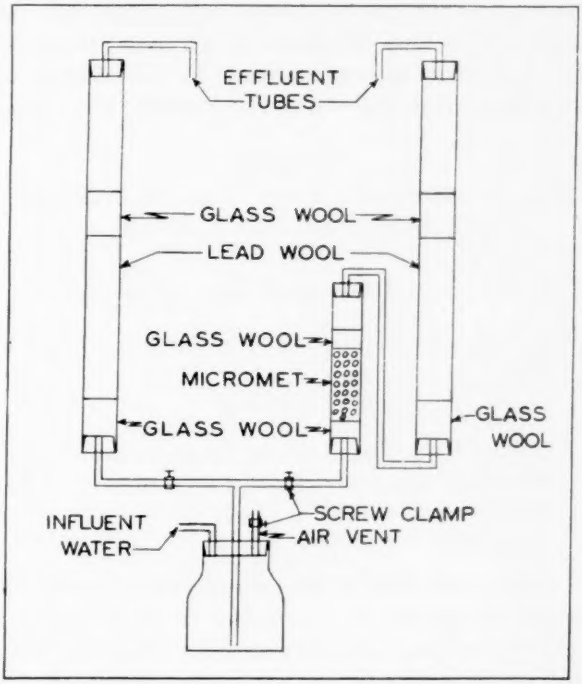


FIG. 1. Continuous Flow Apparatus for Measuring Corrosion of Lead Wool

Two series of experiments were run on lead wool. In the first series, Cambridge tap water, a coagulated and filtered water, with its pH value adjusted with lime to about 8.8, was run simultaneously through a tube containing only lead wool, and also through a set of tubes containing "Micromet" and lead wool, in the order named. The run was continued for 39 days. In the second series, the water used was filtered water drawn from the main of the Cambridge plant, ahead of the lime feeder. This water had a pH value in the vicinity of 6.0, due to the effect of the coagulant. This run was continued for 35 days. In neither case was the flow

of water cut off for any appreciable period of time, but continued at 200 ml. per min. throughout the run.

The quality of the water used remained substantially constant throughout the tests. Table 1 gives average, maximum and minimum analyses derived from the plant records. This table applies to all the experiments cited in this paper. During the period the turbidity of the filtered water ranged from 0.0 to 0.1 ppm., and the hardness was 32 ppm.; the tap water had a turbidity of 0.0 to 0.2 ppm. and a hardness of 42 ppm.

The results of the experiments are presented graphically in Figs. 2 and 3. These figures show that the tap water, with its high pH value, took up only small quantities of lead, about 0.0 to 0.3 ppm., from the lead wool. The amount of lead taken up was increased by the addition of metaphosphate to the water. The amount of the increase was variable, but, in

TABLE 1

*Range of Composition of Waters Used in the Experiments*

(All results in ppm., except pH value)

| TYPE OF WATER | VALUE | COLOR | TOTAL ALKALINITY | NORMAL CARBONATE ALKALINITY | pH | $CO_2$ |
|---|---|---|---|---|---|---|
| Filtered | Average | 1.5 | 11.5 | — | 6.0 | 8.5 |
| | Maximum | 3.0 | 17.5 | — | 6.3 | 10.5 |
| | Minimum | 0.0 | 8.5 | — | 5.9 | 7.5 |
| Tap | Average | 2 | 22.0 | 8.5 | 8.8+ | 0 |
| | Maximum | 2 | 25.5 | 15.0 | 8.8+ | 0 |
| | Minimum | 1 | 17.5 | 5.0 | 8.7 | 0 |

general, was about one-third of the amount taken up by the untreated water. Toward the end of the run, there was a tendency for the lead pick-up of both treated and untreated waters to drop to a low value.

The filtered water, having a low pH value, picked up a considerably greater quantity of lead than the tap water. With few exceptions, the concentration of lead was 0.4 ppm. or greater, and rose as high as 1.3 ppm. At the beginning of the experiment, the metaphosphate-treated water showed a slightly greater pick-up than the untreated water. After 10 days, however, the lead content of the metaphosphate-treated water dropped considerably, while that of the untreated water remained relatively constant. It is evident that the metaphosphate exerted an inhibiting action on the corrosion of the lead wool beyond this point. It is also likely that the inhibiting action would have appeared sooner if a larger concentration of metaphosphate had been used.

## Aging of Lead Pipe

The work so far described led to the conclusion that the practical questions raised concerning the use of metaphosphate in lead pipes could best be answered by using lead pipe which had previously been exposed to

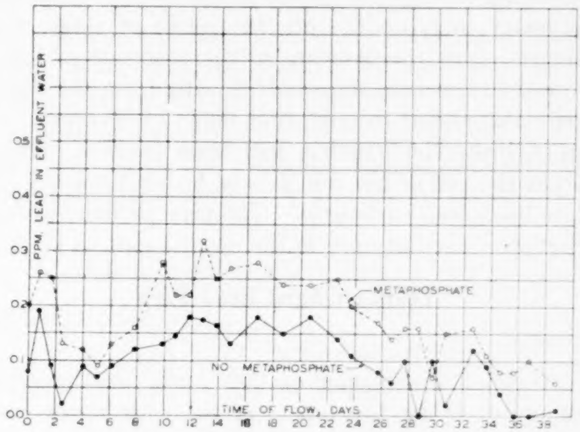


FIG. 2. Solution of Lead From Lead Wool by Cambridge Tap Water

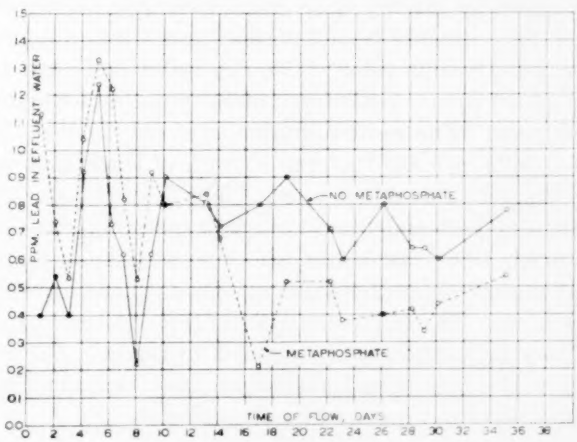


FIG. 3. Solution of Lead From Lead Wool by Cambridge Filtered Water

corrosive water. Use of such "aged" pipe was felt to give a better representation of conditions in a system in which metaphosphate treatment was being introduced for the first time. Consequently a bank of twelve 2-ft.

sections of 1-in. standard lead pipe was set up and connected by means of rubber stoppers and glass tubes. The corrosive water designated in this paper as Cambridge filtered water was passed through these pipes at a rate of 200 ml. per min. for a period of 95 days. The lead content of the water was determined at regular intervals, to determine whether or not corrosion was being diminished by the formation of a protective coating. It is not necessary to reproduce all the results of these determinations since they merely show the decrease in the corrosion of lead with time. At the beginning of the run, the water flowing from the pipes contained 1.0 to 1.2 ppm. lead, and at the end, only 0.07 to 0.30 ppm. These figures indicate that a protective coating had been formed. Examination of the wet pipes at the end of the run showed a thin brownish coating, with traces of white basic lead carbonate. The pipe sections were not allowed to dry out, but were used at once in the experiments to be described.

## Tests on Aged Lead Pipe

### *Standing Samples*

The first experiments performed on the "aged" lead pipe employed the simple technique of filling the pipe sections with water containing the required amount of metaphosphate, allowing them to stand over night, and then determining the lead content of the water. Three types of water were used—Cambridge filtered water and Cambridge tap water, the properties of which have already been described, and Cambridge raw water, a surface water of fairly high color. The raw water had a pH value of 6.9, an alkalinity of 16 ppm., a hardness of 32 ppm. and a carbon dioxide content of 2.0 ppm. The results obtained are presented in Table 2.

Again, the results indicate that the amount of lead taken up is largely a function of the pH value of the water. The filtered water dissolved the largest quantity of lead and the addition of metaphosphate reduced the amount dissolved. The raw water was intermediate in amount of lead taken up and the metaphosphate did not produce any consistent change in the lead pick-up. The tap water took up the smallest quantity of lead, but the addition of metaphosphate tended to increase the lead pick-up. The addition of 10 ppm. of metaphosphate more than doubled the mean concentration of lead accumulated by the tap water.

### *Flowing Samples*

Equipment similar to that used for the experiments on lead wool was set up, with a section of "aged" lead pipe substituted for the tube of lead wool. Two series of tests were made with this equipment, using filtered water and tap water, both with and without metaphosphate. The mode of operation was as follows:

The flow through the apparatus was adjusted to 200 ml. per min. and flow was continued during the day. At night, and over weekends, the apparatus was shut off, and the water allowed to stand in the pipes. Samples were taken both at the end of the day, when steady flow conditions had prevailed for about eight hours, and upon first starting the apparatus in the morning. These samples thus represented, respectively, steady flow conditions and the conditions obtaining after long periods of standing. The values obtained simulate the best and the worst conditions which would be encountered in practice.

The results of the experiments are shown graphically in Figs. 4 and 5, which include the values for both the flowing and standing samples. The metaphosphate concentration in the treated portion of the water is

TABLE 2

*Tests of Aged Lead Pipe—Standing Samples*

| WATER | METAPHOSPHATE IN PPM. | LEAD TAKEN UP, PPM. | | | |
|---|---|---|---|---|---|
| | | Individual Values | | | Mean |
| Raw | 0 | 0.96 | 1.28 | 1.36 | 1.20 |
| | 2 | 1.12 | 1.20 | 1.16 | 1.16 |
| | 4 | 0.76 | 1.00 | 0.92 | 0.89 |
| | 10 | 1.00 | 1.08 | 1.12 | 1.07 |
| Filtered | 0 | 2.04 | 3.24 | 3.12 | 2.80 |
| | 2 | 1.40 | 2.48 | 2.56 | 2.15 |
| | 4 | 1.72 | 2.72 | 2.48 | 2.31 |
| | 10 | 0.96 | 1.00 | 1.04 | 1.00 |
| Tap | 0 | 0.31 | 0.36 | 0.32 | 0.33 |
| | 2 | 0.35 | 0.42 | 0.48 | 0.42 |
| | 4 | 0.28 | 0.52 | 0.66 | 0.49 |
| | 10 | 0.68 | 0.78 | 0.90 | 0.79 |

also given. The numerical values appended to the plots for the standing samples represent the number of hours of standing.

Considering first the results obtained with the filtered water (low pH value), it is evident that the metaphosphate diminished the amount of lead present in both standing and flowing samples. The few exceptions to this statement are not significant. The actual concentration of lead in the standing samples was quite high, seldom falling as low as 1 ppm., even for the metaphosphate-treated water. The lead concentration in the flowing samples diminished gradually from about 0.3 ppm. to 0.1 ppm. in the untreated water, but rarely rose above 0.1 ppm. in the water containing metaphosphate. It will also be noted that the metaphosphate dose was relatively low in this series of tests, ranging from 1 to 2 ppm.

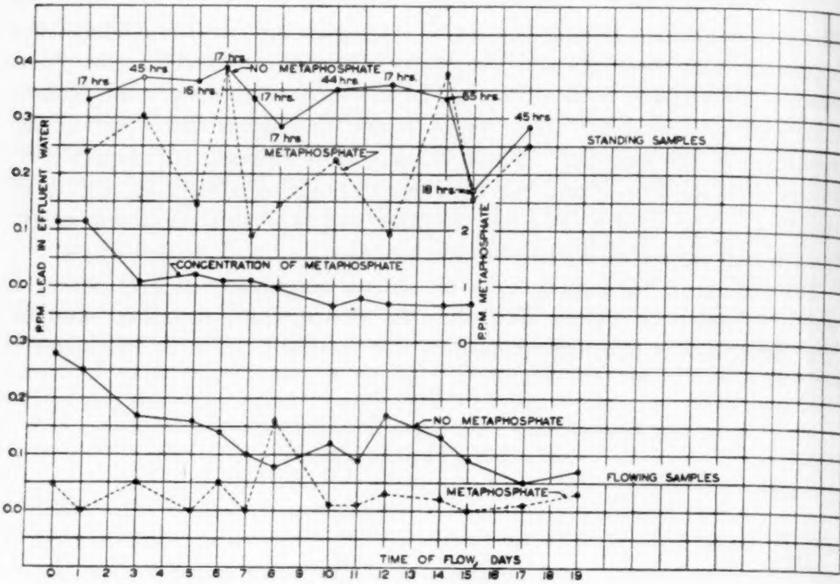


Fig. 4. Solution of Lead From Aged Lead Pipe by Cambridge Filtered Water


Fig. 5. Solution of Lead From Aged Lead Pipe by Cambridge Tap Water

The results obtained with tap water (high pH value) are quite different as regards the standing samples. The lead pick-up for the water containing metaphosphate was quite high at first and remained somewhat higher than the lead pick-up for the untreated water throughout the run. For both treated and untreated waters, the amount of lead taken up was materially less than that for the filtered water, never exceeding 1 ppm. after the first two days of the run. These results are in line with those previously obtained on lead wool and in the first experiments on the "aged" pipe. On the other hand, after the first day or two, the amount of lead in the flowing samples remained lower for the metaphosphate-treated water than for the untreated water. In both treated and untreated waters the lead pick-up was always less than 0.07 ppm. and was practically zero most of the time for the treated water. The quantity of metaphosphate used was somewhat greater than that employed for the filtered-water experiment, ranging from 2 to 4 ppm.

## Discussion

The authors' experiments tend, in general, to confirm the conclusion reached by Hatch, that metaphosphate is effective in minimizing the pick-up of lead at pH values lower than 7.0. This seems to be true whether the lead surfaces are fresh or coated with deposits of various lead salts.

There is no evidence in these experiments of any long-continued dispersing action by metaphosphate on the deposits found in lead pipes, except in waters of relatively high pH value. For these waters, the amount of lead taken up is normally comparatively low. On this account, the action of metaphosphate in increasing the amount of lead taken up is not so serious as it might be. There is, therefore, no evidence of any grave danger except that inherent in the consumption of water that has stood for long periods in the lead pipe. This danger has always been recognized wherever lead pipe has been used and the introduction of metaphosphate treatment adds no new element to the situation. Furthermore, it is unlikely that metaphosphate treatment would be used in conjunction with the maintenance of a high pH value, since most recent work indicates that metaphosphate treatment is most effective at low pH values.

There is, however, one notable exception to the statement regarding the use of metaphosphate in conjunction with high pH values. When metaphosphate is used in a softening plant as a substitute for recarbonation, the effluent water has a relatively high pH value. Under these circumstances, the amount of lead taken up by water standing in lead pipes might be increased by the addition of metaphosphate. It would seem

advisable to initiate studies to determine whether or not such an increase actually does occur.*

In conclusion, the authors would point out that there is still a need for field investigation of this problem. This investigation should take the form of a study of the lead concentrations in the water delivered to consumers having lead pipe and services, both before and after the introduction of metaphosphate treatment. Such a study, in conjunction with the laboratory results already obtained, should furnish a final answer to the question of the effect of metaphosphate on lead.

## Summary and Conclusions

Laboratory studies were made on the influence of metaphosphate on the quantity of lead picked up by water passing through lead wool and through lead pipe previously exposed to corrosive water. The conclusions reached are as follows:

1. In water having a pH value of 7.0 or less, the addition of metaphosphate materially reduces the amount of lead taken up by the water.
2. Under certain conditions, the addition of metaphosphate to a water having a pH value of 8.8 will increase the amount of lead taken up by the water.
3. Since the amount of lead taken up by waters of high pH value is relatively small, the increase due to the addition of metaphosphate does not seem to the authors to indicate any serious danger to public health, except possibly in softened waters which employ metaphosphate as a substitute for recarbonation.

## References

1. Ruchhoft, C. C. and Kachmar, John F. Study of Solubility of Two Lead Salts in Dilute Solution With Special Reference to the Lead Hazard in Drinking Water. Jour. A.W.W.A., **34:** 85 (1942).
2. Hatch, G. B. Inhibition of Lead Corrosion With Sodium Hexametaphosphate. Jour. A.W.W.A., **33:** 1179 (1941).
3. *Standard Methods for the Examination of Water and Sewage.* Am. Public Health Assn. and Am. Water Works Assn., New York (8th ed., 1936).

* "If a softening plant is operated so as always to maintain a slight protective coating in the mains, there should be no exposed lead pipe to dissolve."—*C. P. Hoover*

# Stabilization of Lime-Softened Water

*By Charles P. Hoover*

IN AN article on "Recarbonation of Softened Water" published in July 1927 (1), the author disposed of the whole subject of stabilization of lime-softened water in two sentences which read as follows:

"Lime-softened water may be cheaply and satisfactorily stabilized by recarbonating it with carbon dioxide gas.

"Enough carbon dioxide should be added so that the carbonated water will show just a faint trace of color when phenolphthalein is added."

The author's conception of a stabilized water, at that time, was a water having a balanced condition not readily destroyed; in other words, a water that will not deposit any of its constituents. At that time prevention of excessive scale formation seemed to be the pressing problem. The Columbus Water Softening and Filtration Plant had been in operation for nineteen years without recarbonation and the softened water formed so much deposit that the mains deteriorated in carrying capacity much more rapidly than mains in many other cities. In a study comparing the value of the Williams-Hazen coefficient, *C*, for various years of service (2), the values for Columbus were noticeably lower than any of the other cities used for comparison. Many meters became sluggish because of deposits and undoubtedly some revenue was lost because of under-registration.

That these conditions continued for nineteen years with very few consumer complaints indicates that the public, at least, was not dissatisfied with the water or conditions set up in the distribution system. So far as can be remembered, there were received no complaints of rusty or red water from either the hot or cold water taps. There were some complaints relative to stoppages in heating coils and other small pipes, but these were not numerous. In 1905, three years before the Columbus plant was put into operation, W. B. Gerrish, Superintendent of Water Works at Oberlin, Ohio (3), reported similar results at Oberlin, where the first municipal water softening plant in the United States was built. It was his belief that to obtain best results there should be about six days of sedimentation

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A paper presented on June 24, 1942, at the Chicago Conference by Charles P. Hoover, Chief Chemist, Water Softening and Filtration Plant, Columbus, Ohio.

before filtration. Long storage, apparently, was his formula for stabilizing lime-softened water. In discussing the paper, George Whipple, one of the outstanding sanitary engineers at that time, concluded that if municipal water softening plants were to be developed, as seemed likely, recarbonation should receive very careful attention.

## Development of Recarbonation

Provision for a recarbonation plant, apparently an unsuccessful one, was made in the first municipal water softening enterprise in North America, at Winnipeg, Can., in 1901, and, although Mr. Whipple, as well as others, predicted more than 30 years ago that if water softening plants were to develop, recarbonation must receive careful attention, little was done about it, outside of laboratory experiments, until 1921, when Nicholas Hill built a plant at Defiance, Ohio. Throughout these years very few water softening plants were built, obviously because of the expense involved in building large basins and because of the fear of reducing the carrying capacity of distribution systems.

At Columbus, it was found that the carrying capacity of the mains could be largely restored at a nominal charge of from $\frac{1}{2}$ to 5 per cent of the cost of the mains, this amount being put on the books, by those in responsible charge, as a penalty for pioneering. A part of the distribution system has been cleaned since recarbonation was inaugurated and it was planned to clean more of the main lines, but now that sodium hexametaphosphate* has been added to the water supply (since April 1939) it is hoped that further mechanical cleaning will be unnecessary. During the last six months the scale in the distribution system is softening so that now when a fire hydrant is opened in a residential section, the increased velocity causes the adherent scale to let go, with the result that the turbidity of the flush water sometimes exceeds 5,000 ppm. (Fig. 1). A partial analysis of sludge flushed from the mains is as follows:

| *Ingredient* | *Percentage* |
|---|---|
| $SiO_2$ | 3.68 |
| $R_2O_3$ | 8.64 (very little Fe) |
| CaO | 36.20 |
| MgO | 7.60 |
| $CO_2$ | 27.00 |
| Undetermined | 16.88 |

It is planned to attempt to flush much of this deposit out of the mains late at night so that the water will be clear before the consumers have occasion to use it.

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* The sodium hexametaphosphate referred to throughout this paper is the product commercially known as "Calgon."

In recent years, i.e. since recarbonation of lime-softened water has come into almost general use, stabilization of water has taken on a new meaning which implies that a stable water is one which will not lay down too much scale nor dissolve the metals with which it comes in contact. In other words, a stabilized water now generally is considered to mean one that

FIG. 1

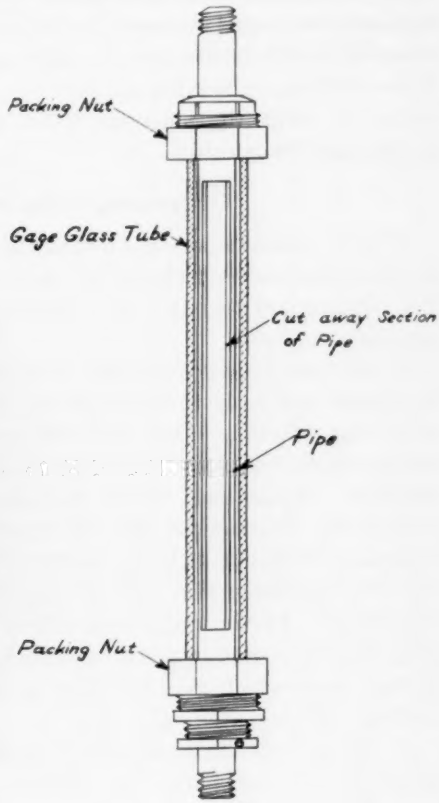


FIG. 2

FIG. 1. Water Collected From Consumer Tap Shortly After Flushing Fire Hydrant; turbidity, 5,000 ppm.

FIG. 2. Visible Test Pipe; suggested by John W. Krause, Chief Engr., La Grange, Ill., Water Works

should behave itself in the distribution system. It is probably impossible, at this time, to write a specification for an ideal water (i.e., an oxygen-bearing water) in terms of alkalinity and pH, because if the alkalinity and pH are such as to build up a protective film, some incrustation will develop and, *vice versa*, if the water is deficient in alkalinity and pH, the water will not be free from corrosive qualities. The best that can be expected, at

least for the present, is that neither alternative will be very serious. If water has a zero, or very low, oxygen content, the problem is much simpler.

Some water works engineers and chemists in this country, and many from foreign countries, who have visited the Columbus plant, take the attitude that the responsibility of the water department ceases when the water leaves the main distribution system. It is contended that water cannot be produced or treated so that it will behave itself beyond criticism when delivered into homes or buildings which have inferior plumbing and make-shift water heating appliances. It is pointed out that this is especially true when the consumer insists on heating the water to an unnecessarily high temperature.

## Obligations of the Water Department

It is the author's personal feeling that the obligation of the water department extends beyond the point where the water leaves the main distribution system and that it is its duty to make an all-out effort to produce a satisfactory water.

It has been pointed out that, in several cases lately, operators of water treatment plants have been disturbed by the problems that have arisen when the softening plant first delivered softened water into distribution mains which for many years had carried water having different characteristics. It has been asked what general measures should be taken to correct the situation as well as to reduce the public clamor that results from new conditions. In answering this question, it should first be pointed out that anything like "public clamor" is entirely without the author's experience. In the great majority of instances consumers' reaction has been favorable, and in many instances, enthusiastic. There are, however, certain steps which may be taken to moderate the immediate effects of a change-over to softening:

1. Do not tell the public ahead of time. It is better psychology to let them discover the change themselves.

2. Do not recarbonate for several weeks. Without recarbonation, the softened water is unstable and lays down enough protective scale to coat or whitewash the interior of the mains. This can be determined by putting in a few test pipes, such as that shown in Fig. 2. It is advisable to place these test pipes both at the plant and at the far ends of the distribution system. Periodically both hot and cold samples should be collected from different parts of the distribution system, for the determination of iron.

3. Do not use phosphates at the start, as they prevent the accomplishment of protectively coating or "liming up" the mains. Their use may also loosen up rust deposits already in the mains or release green deposits of copper from meters.

4. If the water is oxygen-free well water, keep it as free from oxygen as possible. Do not aerate unless there is some unusual or special reason for doing so.

5. Lime should be used in quantities large enough to precipitate as much magnesium as possible, even though the treated water may contain from 20 to 30 ppm. of caustic alkalinity. Under-treatment with lime precipitates the magnesium only partially and its presence may later make its appearance as magnesium silicate in heating coils. Magnesium reduction

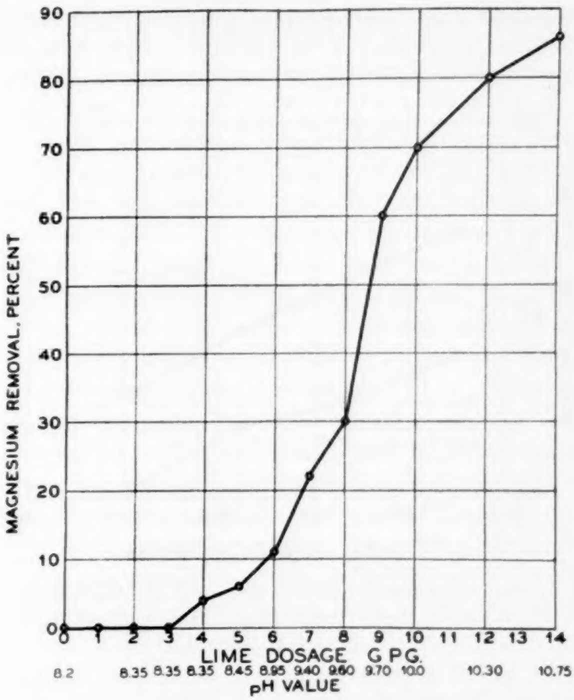


FIG. 3. Removal of Magnesium From Scioto River Water by Use of Varying Dosages of Lime

at various pH values is shown in Fig 3. That there is still much more to learn about the optimum methods of magnesium removal in lime softening of water is evidenced by the difference in actual and reported theoretical figures. Compare the theoretical solubility of Mg $(OH)_2$ (as ppm. Mg.)* *vs.* pH with the actual Mg present.†

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* Theoretical data from Kline (4) and Langelier (5).

† Based on a series of tests at the Columbus Water Softening and Filtration Plant.

| pH | Mg Theoretical | Mg by Experiment |
|---|---|---|
| 9.82 | 11.6 | 21 |
| 10.0 | 5.0 | 15 |
| 10.2 | 4.2 | 9 |
| 10.4 | 0.8 | 5 |
| 10.6 | 0.3 | 4 |
| 10.8 | 0.1 | — |

6. Addition of aluminum sulfate facilitates magnesium removal and should be used along with the lime and soda ash. Figure 4 shows greater magnesium removal with equal amounts of lime, but addition of aluminum sulfate.

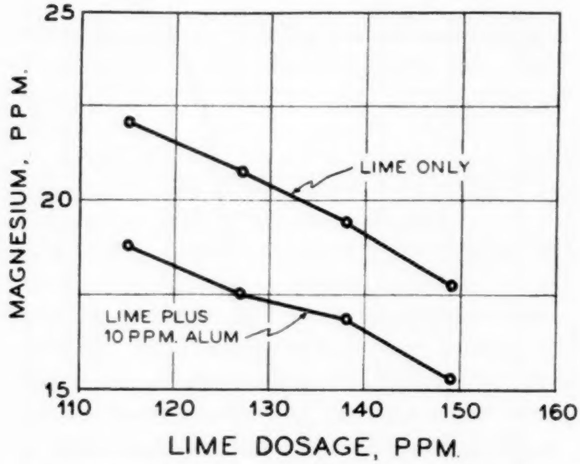


FIG. 4. Effect of Aluminum Sulfate on the Removal of Magnesium; based on data from W. W. Aultman, Water Purif. Engr., Metropolitan Water Dist. of Southern California

Stabilizing water, so that it will behave itself in the distribution system, is a difficult problem. In lime-soda ash softening there are seven general methods, with modifications, used as aids in stabilization:

1. Long reaction time
2. Recarbonation
3. Addition of raw water to softened settled water ahead of filters
4. Addition of sodium bicarbonate, soda ash or lime
5. Filtration through sand filters
6. So-called sludge blanket filtration
7. Treatment with phosphates, such as sodium hexametaphosphate.

Various combinations of these seven methods may be used to good advan-

tage. All of them have certain advantages and disadvantages, which will be discussed briefly. No attempt has been made to list them in the order of their importance.

1. *Long Reaction Time*

As lime-soda-softened water is allowed to stand, the dissolved calcium carbonate, which is present in a supersaturated state, slowly precipitates. The longer the time of standing, the better the results.

The experience at Oberlin, Ohio, shows the effect of long standing. Originally, the plant used a large reservoir to store the raw water for about 30 days before softening. Troubles due to incrustation of mains were quite annoying, until the procedure was reversed, using the reservoir to store the water after softening.

When the change was made it was hoped that there would be natural recarbonation by atmospheric carbon dioxide ($CO_2$), but instead it was found that there was a reduction of alkalinity rather than any noticeable conversion to bicarbonates. For example, water having a total alkalinity of 65 ppm. and phenolphthalein alkalinity of 35, was found, after a month's storage, to have corresponding alkalinities of 45 and 23. This water was practically stable, as noted by both chemical analyses and observation of incrustation on the mains. It is of interest to note that the alkalinity of this water is all present as normal carbonate.

Another plant making use of the long period of reaction is the St. Louis Chain of Rocks plant. The total theoretical retention period preceding filtration is about three days. After filtration, the water is stored in large reservoirs, the drop in alkalinity in these reservoirs being 1 ppm., and less than 1 ppm. in the distribution system. The total alkalinity of the delivered water averages about 40, with a phenolphthalein alkalinity of 11.

The disadvantage of the long reaction time is the cost of building large enough basins to provide the long storage. In the case of a well supply, the long storage period causes an undesirable warming up of the water during the summer months.

2. *Recarbonation*

In the time since recarbonation has come into general practical use, the conception of its function has changed almost completely. The idea, during the development of the process, was to add enough carbon dioxide to the softened settled water to convert all normal carbonates to bicarbonates; in other words, to recarbonate to a pH value of about 8.3. When this was tried on a plant scale, however, it was found that the water had an aggressive reaction on deposited scale, on the precipitates already accumulated in the basins and on the incrusted filter sand. In fact, the water after re-

carbonation would dissolve scale and precipitates to such an extent that the alkalinity in many cases would be more than doubled. In the light of present knowledge of calcium carbonate saturation, the increase in alkalinity can be explained readily, and computed with accuracy by means of the nomograph of the Langelier formula (6). For example, to be in chemical balance, a sample of softened recarbonated water having an alkalinity of 35 ppm., total solids of 300 ppm. and calcium of 20 ppm. should have a pH of 8.9, and to put it in chemical balance at a pH of 8.3, the alkalinity would have to be about 130, or almost four times the alkalinity required for a pH of 8.9.

Another difficulty in recarbonating lime-softened settled water to bicarbonates is the tendency to put the finely suspended calcium carbonate and magnesium hydroxide back into solution. If, for example, a sample of softened, settled water were divided into two portions, and one portion recarbonated to all bicarbonates, the alkalinity, after filtering both, will be higher in the recarbonated sample. It is entirely probable that the increase in alkalinity is due more to the dissolving of the magnesium hydroxide than the calcium carbonate, because magnesium hydroxide can be dissolved very readily by carbon dioxide, while calcium carbonate is much more difficult to put into solution.

In view of the fact that lime-softened water with an analysis of alkalinity, 40 or under, hardness, 85 or under and calcium, 18 or under, must have a pH value of about 8.9 to be in equilibrium, and keeping in mind that low alkalinity oxygen-bearing water should have a plus index of from 0.4 to 0.8, to prevent red water troubles, it is apparent that recarbonation of low alkalinity water should be carried to a pH value of from 9.3 to 9.7. This will, however, leave a water that will incrust the sand filters, but it is believed to be a better policy to keep the trouble in the plant, than to put out a water that would be aggressive to the consumers' plumbing. If water with such a highly positive index lays down too much scale, this can be reduced by adding a trace of sodium hexametaphosphate.

### 3. *Addition of Raw Water*

This method is practical and applicable only under certain conditions. It may be used to advantage with well water having a high carbon dioxide content and no harmful bacteria. Unless the mixture is filtered and sterilized, it is not considered good practice to blend surface water that has a low carbon dioxide content, or a high turbidity, or that which is not bacterially safe. It must be filtered to remove turbidity and also must be sterilized to kill the bacteria, since the excess lime which is relied upon to kill the bacteria is neutralized by the raw water.

4. *Addition of Sodium Bicarbonate, Soda Ash or Lime*

Sodium bicarbonate may be used in place of carbon dioxide to neutralize excess lime, or it may be used to increase the alkalinity and lower the pH value. With an increase in alkalinity, the pH value may be lowered without lowering the saturation index. The addition of soda ash or lime is used to increase the alkalinity and pH so that the water will have a positive saturation index. Lime treatment is cheaper than soda ash, but when used to adjust pH it has the disadvantage of hardening the water.

5. *Sand Filtration*

Partial stabilization of lime-softened water is effected by sand filtration, particularly if the sand grains are incrusted with scale. The stabilizing effect may be obtained even if the grains are not coated, after a layer of precipitate has formed on top of the sand bed. The softened water in contact with the precipitate simulates somewhat the chemical balance test as made with calcium carbonate in the laboratory. The alkalinity of the softened water in some plants drops from 20 to 35 ppm. in passing through the filters.

The removal of hardness by sand filtration causes the sand to grow in size and, unless special precautions are taken, such as surface wash or frequent scraping and screening of the top sand layers, the grains of sand cement themselves together and form hard lumps. Usually when sand filters are used to remove hardness the filters have to be reconditioned at about five-year intervals and new sand supplied at least every ten years.

Addition of small quantities of sodium hexametaphosphate to the softened settled water will prevent removal of alkalinity by filtration, and will inferentially prevent sand growth; but removal of hardness by filtration, even in spite of the extra cost of filter maintenance, is a cheap softening process and most operators prefer not to interrupt it by the addition of a prohibitor.

6. *Sludge Blanket Filtration*

New patented devices, of which there are four different units now marketed, employ upward flow through a sludge blanket for water softening or clarification. Fundamentally, these machines are similar, in that the precipitation of solids occurs in the presence of a large amount of previously formed sludge, and they combine flocculation or mixing, settling and continuous removal of sludge in one tank.

Coagulation and water softening reactions are hastened due to the contact of the chemically treated water with tremendous areas of sludge, and clarification is promoted because of the upward filtration of the coagulated water through the sludge blanket.

The principal advantages are that the surface area of the basins can be greatly reduced and slightly more hardness removed per pound of softening reagent used. It seems, however, that this equipment offers more possibilities for stabilizing water than have been taken advantage of so far. A suggested improvement involves carbonating the excess lime, required to precipitate the magnesium, and then conditioning the carbonated effluent in a second sludge blanket device with magnesium-free crystallized calcium carbonate sludge.

7. *Treatment With Phosphates*

The increasing popularity of this method of stabilizing water probably is due to the small amount of chemical required. While the cost of the material, on the weight basis, is high, the cost of treatment, due to the low dosage, is not excessive. The limitation of this treatment is that calcium only is sequestered, and it has been observed that some of the scale deposited in hot-water heaters from lime-softened water, following treatment with sodium hexametaphosphate, is almost 100 per cent magnesium silicate. It is important, therefore, that the magnesium content of lime-softened water be reduced as far as practicable before applying the metaphosphate.

In actual practice, any attempt to stabilize water is almost always a combination of two or more of the methods outlined.

## Theoretical Work and Practical Operations

It must be admitted that there is much confusion regarding corrosion of water mains and heaters, but the author does not agree with T. M. Riddick's statement (7) that "some of the many pitfalls into which water works men have been thrown in their study of corrosion are the overemphasis on chemistry (or pseudo-chemistry) . . . too great a haste in the publication of new theories and methods. . . . " The author is convinced that more progress has been made as a result of scientific theories advanced in the last decade than in all previous water works history, particularly in the work of John Baylis, W. F. Langelier and Frank E. Hale and the practical applications of Paul Weir and others.

There is a tendency to condemn theoretical work if it does not check 100 per cent with observed data. An attempt should be made to carry both the theoretical and practical work still further to secure better agreement with calculated and observed results. The author's own observations have not checked exactly with theoretical calculations, so he referred to Professor Langelier the following questions regarding his formula (8), which has been found helpful in corrosion studies and useful in explaining the behavior of water produced in previous years, where the only information available was the record of chemical analyses:

*Question 1:* Should not the Langelier formula account for the magnesium and silica content of the water?

*Reply:* Neither magnesium ions nor silica are involved in the calcium carbonate equilibrium. Moreover, the pH required to precipitate magnesium hydroxide or the basic carbonate is considerably higher than for calcium carbonate. This can be proved theoretically and there is abundant experimental evidence of this fact in water softening experience. As to silica, the reactions are complicated by hydration effects, but there is evidence to indicate that the $SiO_3$ ions necessary to form magnesium silicate in aqueous solution cannot exist in the pH range of normal waters. Theory indicates that since the $pK_2$ value for $H_2SiO_3$ equals 12.0, only 1 per cent of the total silica can be present in ionic form at pH 10.0 and only 0.1 per cent at pH 9.0. The fact that silica precipitates from hot water may be due to a lowered solubility brought about by hydration effects.

*Question 2:* The influence of temperature, according to the Langelier formula, is much greater than it is when determined by the so-called "Marble" test. For example, on a sample of water recently tested in our laboratory the difference in $pH_s$ at 70°C. and 20°C. was 0.8, whereas the Marble test showed only 0.3.

*Reply:* There is need of further work on this phase.

*Question 3:* Why may water, even though it is high in calcium and though it has a positive index, be objectionably corrosive? Personal experience indicates that low alkalinity water with high calcium sulfate content, even though it has a positive index, can be quite corrosive.

*Question 4:* It is thought that water high in total solids may be quite corrosive even though it has a positive Langelier index. Do you think this is true?

*Reply:* If the saturation index is to be used as a corrosion index, it is of course necessary to assume that the precipitated salts will adhere to the pipe walls to form a protective coating. If experience in practice indicates that a water with a sufficiently high positive index fails to protect against corrosion, it would be my opinion that certain dissolved salts not directly involved in the equilibrium are capable of altering the physical character of the precipitate, either by peptization or coagulation, such that adherence to the pipe wall is either lacking or not uniform. Theoretically, a high sulfate concentration would coagulate either the colloidal calcium carbonate or the hydrated iron oxide, which, under conditions of good protection, undoubtedly "cements" the carbonate to the pipe wall. These thoughts are in line with the idea that silicate protection results from coagulation and deposition induced by temperature effects. You will note that this theory supplements rather than displaces the saturation index theory.

*Question 5:* What is an ideal water for general and municipal use? That is, about what should its alkalinity, its pH, $pH_s$, calcium, hardness, total solids and $SiO_2$ be?

*Reply:* There is no "ideal" water. (Answers to this question by F. H. Waring, Ohio State Department of Health, H. E. Jordan, American Water Works Association, John Baylis, Chicago Bureau of Engineering, A. V. Graf, St. Louis Water Department, were all the same—"do not know.")

## Information for Control and Study of Recarbonation

The author believes that the determination of normal carbonates, bicarbonates and caustic alkalinity by the methyl orange phenolphthalein titration procedure gives valuable information on the control and study of stabilization. Admitting that the results are not entirely correct, they do, after all, give an indication of whether or not the water tested contains normal carbonates in an amount sufficient to satisfy the calcium at its solubility limit. In other words, calcium carbonate cannot be precipitated from water if it is not present. For example, in the early days of recarbonation at the Columbus plant, water of about the following composition was produced: total alkalinity, 26; phenolphthalein alkalinity, 6; calcium, 24; pH, 9; and $pH_s$, 8.9. This water proved aggressive and destructive to hot water tanks and resulted in many complaints from consumers. On the assumption that the phenolphthalein alkalinity, multiplied by 2, gives the normal carbonates in water, it is obvious that the water could not have contained over 12 ppm. calcium carbonate. This is below the solubility limit of calcium carbonate and consequently could not have produced a protective scale. Following this line of reasoning, experience has indicated that water having a high caustic alkalinity may not deposit a protective scale. Riddick (9) states: "It has been known for some time that waters low in carbon dioxide and alkalinity could not be given sufficient lime to form a protective coating."

Returning to the methyl orange and phenolphthalein titration methods, if water contains total alkalinity of 100, and phenolphthalein alkalinity of 95, this leaves only 10 ppm. of normal carbonates (which is below the solubility limit) and about 90 ppm. caustic alkalinity which is highly soluble; therefore, there is insufficient calcium as carbonate to be precipitated from water of this kind under ordinary conditions.

From a consideration of these data, it is concluded that even though calcium is present in fairly large amounts, there should be 0.5 or possibly up to 1.0 equivalent per million of the carbonate radical.

The basis of most of these conclusions is drawn from the results of operation at the Columbus plant. In Table 1 are shown analytical data which

give a brief history of the practice at this plant. The figures are not average results of operation but represent the kinds of water which produced too great, inadequate and satisfactory protective scales.

In the early days before recarbonation, 1908 to 1927, the index was quite high, at about +1.4. During this period no red water complaints were received, but too much deposit was laid down in the mains. The next period, 1928 to 1931, just after recarbonation was put into effect, was marked by the appearance of red water, especially in new installations that had no protective coating. The older pipes and tanks were so well coated that this water had no immediate effect. Even though the water had an index of +0.1, this was not sufficient for protection, due, it is believed, to the absence of sufficient calcium carbonate to lay down a protective coating.

TABLE 1

*Analytical Data on the Columbus Water Softening and Filtration Plant for Various Periods—1908–42*

| PERIOD | METHYL ORANGE ALKALINITY | PHENOLPHTHALEIN ALKALINITY | CALCIUM | TOTAL SOLIDS | pH | $pH_s$* | LANGELIER INDEX |
|---|---|---|---|---|---|---|---|
| | *ppm.* | *ppm.* | *ppm.* | *ppm.* | | | |
| Before Recarbonation | 57 | 33 | 22† | 275‡ | 10.0 | 8.6 | +1.4 |
| Early Period After Recarbonation | 25 | 9 | 23† | 275‡ | 9.0 | 8.9 | +0.1 |
| Intermediate Period, After Recarbonation | 35 | 7 | 20 | 250 | 9.1 | 8.9 | +0.2 |
| Present Period | 39 | 18 | 21 | 235 | 9.7 | 8.9 | +0.8 |

* $pH_s$ = pH saturation.

† Calculated.

‡ Estimated from similar data.

The third period, 1931 to 1939 (during which the bicarbonate alkalinity was higher, but the normal carbonate remained about the same), showed some increase in protection, but, from the observation of hot water tanks and from some complaints, this was still not considered entirely satisfactory even though the index was about double that of the previous period. The present period, in which the alkalinity is predominantly made up of normal carbonates and the index is +0.8, seems to be satisfactory as judged by the lack of complaints. The very striking difference in the condition of hot-water tanks during the intermediate period and the present period is shown very clearly in Fig. 6.

The protective scale, although it is very heavy, does not give complete protection against rusty water when the water is grossly overheated in the tanks. A temperature not to exceed 150° F. is recommended.

Sodium hexametaphosphate has been used during the last three years and has so stabilized the water that there is little or no drop in the alkalinity through the distribution system. Extensive tests are being made to determine whether or not its use influences corrosion, but the results will not be available for another year.

Metaphosphate prevents, or largely prevents, calcium scale formation in cold water pipes, but not in hot-water tanks. The question, why, naturally arises. The answer seems to be that the water in the hot-water tanks is held for hours at a high temperature, during which time the metaphosphate is reverted to the orthophosphate, thus losing its ability to sequester calcium, or perhaps producing a scale of calcium orthophosphate.* The results of phosphate reversion tests are shown in the following tabulation:

| *Tank* | *Distance From Plant* | *Reduction* | *No. of Tests* |
|---|---|---|---|
| No. 1 . . . . . . . . . . . . . . . . . . | 2 mi. | 47.5% | 71 |
| No. 2 . . . . . . . . . . . . . . . . . . | 6 mi. | 51.5% | 65 |

The reversion of metaphosphate to orthophosphate in hot water tanks is fortunate, because inhibition of protective scale in hot water tanks, where it is needed, does not occur.

The character of scale deposits in pipes and in water heating devices is very important from the standpoint of protection. This, of course, raises the question of what kind of water will deposit satisfactory protective scale. In the author's opinion, more research work must be done before this question can be answered satisfactorily. One method of approach would be to secure hot water tanks and heating coils used in all types of water supplies, examine the scale both physically and chemically and then compare the analysis of the water used with the character of the scale in each tank. Some work of this kind has been done in the Columbus water plant laboratory. The results of chemical analyses of scale from hot-water devices from Columbus, Dayton, and Springfield, Ohio, and La Grange, Ill. are shown in Table 2. Some discussion of observations made in these studies is in order.

Figure 5 shows a section of a cast-iron heatiing coil from Springfield, Ohio. The scale is extremely dense and tightly adherent. As shown in Table 2, it is composed largely of calcium carbonate, with some iron, a small amount of magnesium and very little silica.

The middle portion of Fig. 7 shows the scale from a Springfield hot-water tank. The same water was used in both heater and tank. The scale from this tank is quite different from the scale in the heater. As shown in the

* Suggested by Samuel Shenker of the staff of the Columbus Water Softening and Filtration Plant.

table, it contains practically no calcium, no magnesium, and is made up largely of a corrosion product of iron oxide and carbonate.

These results illustrate very effectively, the influence of temperature in controlling the character of scale. No magnesium, and practically no calcium compounds were precipitated from Springfield water (pH 7.5) at temperatures maintained in hot-water tanks, but they were precipitated (especially calcium) at temperatures attained in heating coils. The scale in the coils is laid down in such excessive amounts that it soon clogs them, and sometimes causes failure due to the excessive temperature on the fire side, which is brought about by the resistance of the thick layer of scale to heat transfer.

FIG. 5. Section of Cast-Iron Water Heating Coil from Springfield, Ohio

The bottom portion of Fig. 7 shows the scale from a Dayton hot-water tank. As shown in the table, the analysis of the scale is very similar to the scale in the Springfield tank. It also shows that Dayton water with a pH of 7.3 does not deposit appreciable quantities of calcium or magnesium compounds at the temperatures maintained in hot water tanks. There is an interesting difference between the Springfield and the Dayton tanks. The Dayton tank is badly pitted whereas the Springfield tank is not. The only significant difference that could be noted in the two waters, analyses of which are given in Table 3, was that the Springfield water had and index of +0.1, whereas the Dayton water had an index of −0.1.

The top portion of Fig. 7 shows a tank from La Grange, Ill., which was in service for fourteen years. Hard well water was supplied for eleven years

and lime-zeolite water, for three years. Analyses of both waters are given in Table 3. This tank shows more corrosion than either that from Springfield or Dayton and the deposit is made up largely of iron compounds. Here again calcium and magnesium compounds were not deposited to any

TABLE 2

*Scale Analyses*

| SOURCE OF SCALE | CONSTITUENT, PER CENT | | | | | | |
|---|---|---|---|---|---|---|---|
| | CaO | MgO | $CO_2$ | $SiO_2$ | $R_2O_3$ | Zn | Undetermined |
| Coil, Springfield, Ohio | 49.10 | 1.77 | 41.80 | 0.08 | 4.9 | — | 3.16 |
| Tank, Springfield, Ohio | 0.40 | 0 | 7.90 | 2.95 | 43.40 | 5.45 | 39.90 |
| Tank, Dayton, Ohio | 0.10 | 0 | 9.15 | 1.67 | 70.60 | 2.91 | 15.57 |
| Tank, La Grange, Ill.* | 0.10 | 0 | 2.42 | 1.14 | 78.90 | — | 16.54 |
| Tank, Columbus, Ohio | 45.08 | 1.82 | 2.28 | 3.90 | 4.40 | 27.45 | 15.07 |

* Tank in service 14 yr.; hard well water 11 yr., lime-softened zeolite water 3 yr.

TABLE 3

*Water Analyses*

| | SPRINGFIELD, OHIO | DAYTON, OHIO | LA GRANGE, ILL.—BEFORE SOFTENING | LA GRANGE, ILL.—AFTER SOFTENING | COLUMBUS, OHIO—AVERAGE |
|---|---|---|---|---|---|
| Methyl Orange Alkalinity, *ppm* | 270 | 277 | 412 | 97 | 39 |
| Phenolphthalein Alkalinity, *ppm* | 0 | 0 | 0 | 21 | 18 |
| Non-Carbonate Hardness, *ppm* | 68 | 68 | 376 | 6 | 48 |
| Total Hardness, *ppm* | 338 | 345 | 788 | 103 | 87 |
| pH | 7.5 | 7.3 | 6.8 | 9.0 | 9.7 |
| Magnesium, *ppm* | 32 | 34 | 80 | — | 8 |
| Calcium, *ppm* | 92 | 96 | 230 | — | 21 |
| Iron, *ppm* | 0.0 | 0.07 | 1.2 | — | — |
| Chlorine, *ppm* | 7 | 11 | 4 | — | 11 |
| Carbon Dioxide, *ppm* | 20 | 30 | 140* | — | 0 |
| Silica, *ppm* | 10 | 10 | 14 | — | 6 |
| Total Solids, *ppm* | 476 | 488 | 1,361 | — | 251 |
| $pH_s$, 15°C | 7.4 | 7.4 | 7.0 | 8.8* | 8.9 |
| Langelier Index | +0.1 | −0.1 | −0.2 | +0.2 | +0.8 |

* Marble stability test.

degree. The water used most of the time was of high alkalinity and low pH, similar to that of Dayton and Springfield.

Referring again to Fig. 6, the scale from the Columbus 1940 tank, which was supplied with lime-soda ash softened water, is quite different from the scale produced from hard bicarbonate water at Dayton, Springfield and

La Grange. It is more or less porous and non-adherent and is easily flaked off. As shown in Table 2, it is composed very largely of calcium, magnesium and zinc compounds.

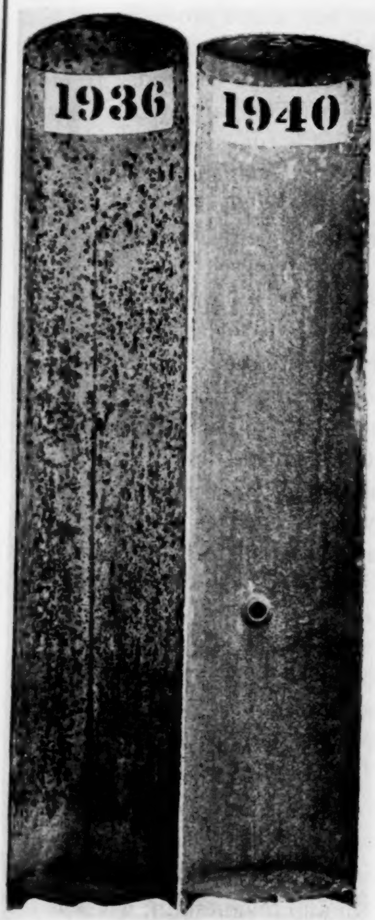


FIG. 6

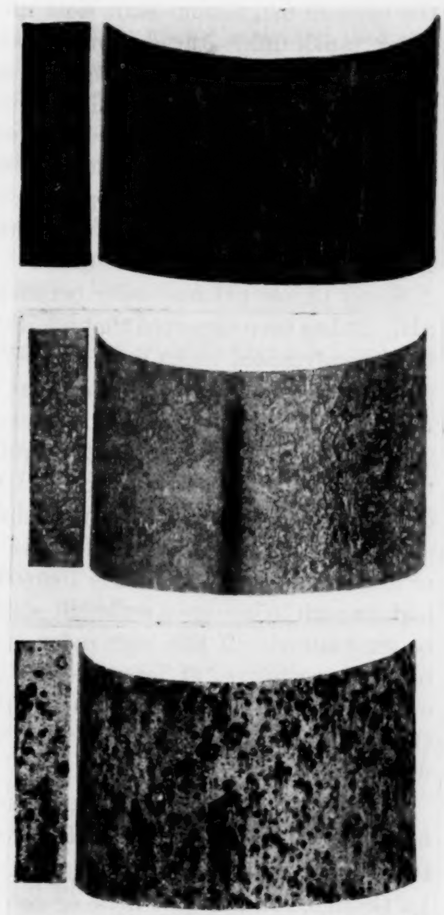

FIG. 7

FIG. 6. Sections of Hot-Water Tanks at Columbus, Ohio, After One Year of Service; average index of 1936 tank about +0.2, of 1940 tank about +0.8

FIG. 7. Sections of Hot-Water Tanks From: *Top*, La Grange, Ill., *Middle*, Springfield, Ohio, *Bottom*, Dayton, Ohio

These results indicate that waters of high alkalinity and low pH do not deposit calcium and magnesium compounds at temperatures maintained in domestic hot-water tanks, but do deposit a hard stone-like deposit, mostly calcium carbonate, in coils where higher temperatures are maintained.

The protective coating produced in the heating tanks is a corrosion product of iron and zinc.

Waters of low alkalinity and high pH, on the other hand, produce a soft scale composed largely of calcium and magnesium, and it is believed that the calcium-magnesium scale does not offer any great protection in hot-water tanks unless the deposition takes place rapidly and in such large quantities that the galvanizing and metal are always covered. In other words, softened water with a high positive index (+0.8) apparently plasters in place on the galvanizing a coating which affords considerable protection, whereas at a low positive index the zinc may be changed to zincate and washed away. This heavy plaster coating gives good protection and eliminates red water troubles unless the water is overheated in the tanks, 140 to 150°F. being recommended.

Water of low pH may offer better protection to zinc than that of high pH. It has been observed that a low pH water may offer better protection to new galvanized tanks than a water of moderately high pH. This may possibly be explained by the fact that waters having a pH value of around 7.5 form one type of corrosion product with the zinc. This product adheres firmly to the metal, affording good protection against further attack. On the other hand, waters having a pH value of 8.5 to 9.0 form an entirely different product which partly washes away and leaves the tank metal exposed for attack. Hence, if water is lime-softened to a low alkalinity, or low-alkalinity water is lime treated, it is believed that a positive index high enough to lay down sufficient scale to offer necessary protection should be maintained. If this high index is not maintained, the water is apt to be more corrosive, at least to new galvanized tanks, than the original untreated water. After the zinc is destroyed, however, the low pH water (7.5) will be much more corrosive to the exposed iron than the higher pH water, i.e., 8.5 to 9.0.

There are indications that the nature of the scale laid down in pipes and hot water tanks may be materially affected by magnesium. It is of interest to notice that the hard scales from the tanks in Dayton, Springfield, and La Grange, contain very little or no calcium and magnesium, whereas the softer scale from hot water tanks and pipes in Columbus (using lime-softened water) contain mostly calcium and magnesium. It has been observed many times in water softening that, when lime is added to water in sufficient quantity to precipitate calcium bicarbonate only, the precipitate formed is granular and dense, whereas if lime is added in sufficient quantity to precipitate both calcium and magnesium compounds, the precipitate is light, fluffy and flocculant, and has a gravity very much less than the calcium precipitate.

These observations suggest that it may be the magnesium present in the scale laid down by lime-softened water that causes it to be soft.

## Summary and Conclusions

1. The term "stabilized water," in this discussion is used in a broad sense, i.e., it means a water that will not lay down excessive scale and that will be as free as possible of corrosive quantities.

2. Early efforts at lime softening, before recarbonation, produced water that laid down excessive deposits, but did not cause red water troubles.

3. Early efforts at recarbonation of lime-softened water produced water that was corrosive to hot-water tanks.

4. The conception of the function of recarbonation has changed almost completely.

5. It is apparently impossible to specify the chemical characteristics of a water that would be ideal for general use.

6. The responsibility of the treatment plant should extend beyond the street mains, and should include, as far as possible, protection of the consumers' plumbing.

7. When introducing a new softened water supply into an old distribution system, which previously carried a hard water, it may be necessary to observe several precautions so that trouble in the change-over may be eliminated. These steps are:

a. Do not publicize date of change-over
b. Hold off recarbonation for several weeks
c. Avoid use of phosphates at start
d. Keep well water as free from dissolved oxygen as possible
e. Add lime dosage sufficient to remove magnesium to minimum
f. Use alum to facilitate magnesium removal.

8. A discussion of the methods in use in stabilizing lime-softened water includes seven methods:

a. Long reaction time
b. Recarbonation
c. Blending with raw water ahead of filtration
d. Addition of sodium bicarbonate, soda ash, or lime
e. Sand filtration
f. Sludge blanket filtration
g. Use of phosphates such as sodium hexametaphosphate.

9. Co-ordination of theory, operating observations and the results of practical experiments is to be encouraged. In work where the theory fails to check with observed results, criticisms should be constructive, endeavoring to account for the differences.

10. Particular reference is made to Langelier's saturation index theory.

Differences in observed and calculated results are discussed, and explanations as to possible causes of these differences are proposed.

11. Observations made over a long period of operation of the Columbus Water Softening and Filtration Plant indicate that, with a water of low alkalinity, a high positive saturation index (+0.8) is desirable for best results.

12. The amount of calcium carbonate present, as determined by the usual alkalinity titration, is a useful measure of the stability of the water. For good protection, the water should be saturated with calcium carbonate at the pH maintained.

13. Sodium hexametaphosphate sequesters calcium and softens deposits in cold-water lines, but it does not prevent deposition of calcium scale in hot-water tanks. This is fortunate and is probably due to the reversion of the metaphosphate to orthophosphate, caused by the action of prolonged heating. The results of extensive tests being made at the Columbus plant to determine whether or not sodium hexametaphosphate inhibits corrosion in hot-water tanks will not be available for another year.

14. Studies, though not covering the entire range of pH values, have been made to determine the kind of scale produced from different waters. The results indicate the following trend:

a. Water that is low in pH value (7.2 to 7.5) and high in alkalinity forms a dense protective scale when held at the temperature of hot water tanks. This scale prevents red-water troubles and is a corrosion product of the iron and zinc, containing no calcium or magnesium. This same water, at the temperature of hot-water coils will lay down an excessive amount of dense hard adherent calcium carbonate scale.

b. Water high in pH and low in alkalinity, e.g., lime-softened water having a high positive index (+0.8), produces an extremely heavy coating of chalky scale, high in calcium, magnesium and zinc, in hot-water tanks. This scale satisfactorily protects the tank unless the water is heated to an excessively high temperature.

c. A water high in pH, low in alkalinity, having a low positive index produces a similar scale but not in sufficient quantity to cover the zinc adequately, with the result that the part of the zinc is converted to zincate and is easily washed away.

d. Water of low alkalinity, with a low pH value (7.5), when heated in a new galvanized hot-water tank, produces an altogether different type of scale; i.e., a corrosion product that is adherent and protective.

15. It is believed that magnesium in scale causes it to be soft and flaky. Magnesium is found in scale produced from a water of high pH, but not in scale produced from one of low pH.

16. Experiments on scale production are being continued.

The author wishes to acknowledge the assistance of Merrill Riehl, of the Columbus Water Softening and Filtration Plant staff, in the preparation of this paper.

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**Discussion by *Daniel H. Rupp.*** * In discussing the paper by Mr. Hoover, the writer proposes to append some observations on the experiences with water stabilization at Topeka, Kan., where, for the past twelve years, the water department has practiced lime-soda softening with recarbonation by oil-fired combustion gases from steam boilers.

Throughout this period no trouble has been experienced with cold water corrosion or scale, the effluent pH being maintained at about 9.1 to 9.4. In certain places it has been noted that considerable zinc precipitate appears in the water, making it milky in appearance and some loss of galvanizing has been detected in hot-water tanks. Some few water heater coils have been plugged with a scale containing principally magnesium silicate, and no carbonates. In a few cases, too, soluble salts were present in the scale, indicating, of course, that the coils have been badly overrated and used as evaporators.

A dosage of 0.25 ppm. (2 lb. per mil.gal.) of sodium hexametaphosphate has been used for the past year and a half to obviate scale formation in the hot-water coils and tanks and to prevent formation of zinc precipitate in the galvanized house piping. Practically no complaints of scale in hot-

* Water Dept., Topeka, Kan.

water heating coils or tanks or in house piping have been made since this treatment was initiated. The pH of the effluent in 1940–41 was 9.5 to 9.6.

It should also be mentioned, however, that during the previous period, under drought conditions, the water was more highly mineralized than during the past two years when the river water was much less mineralized, so that the present effluent actually carries less silica.

Previous to the use of metaphosphate, the water heating device (a steam coil in a tank) at the Filtration Plant plugged up with scale and had to be cleaned every month. Since the metaphosphate treatment began, however, the period between cleanings has been extended to over a year. The scale formed in the device is practically free of carbonates.

On discontinuing metaphosphate treatment for a month it was found that dead-end mains had to be flushed much more frequently.

The local central steam heating plant has advised that less satisfactory softening efficiencies obtain with the metaphosphate-treated water than formerly. Finally, it has been found that the temperature of heating water has a great effect on the amount of silica scale.

**Discussion by *Owen Rice*.*** Out of his long experience Mr. Hoover has dealt fully with the necessity for stabilization of lime-soda softened water and with various steps in the development of recarbonation and the other methods used to accomplish this end. Hence, it will not be necessary to touch on the historical aspects of the subject. Since the writer has had numerous opportunities during the past five years to discuss this problem with most of the operators of softening plants in this country, he will try to present a comprehensive review of present practice.

No doubt many water works men have been puzzled by the conflicting statements which have appeared. Thus, on the one hand, it has been said that lime-soda softened water may be stabilized by long storage or by recirculation of sludge, or that trouble with scale still exists while using a water so treated; that recarbonated water is corrosive or that it is perfectly satisfactory, and so on. During the last five years, not only has considerable information as to the effectiveness of sodium hexametaphosphate in stabilizing water been accumulated, but it has been possible to explain satisfactorily, at least to the writer, the reasons for these conflicting reports.

## Storage and Sludge Blanket Filtration

As mentioned by Mr. Hoover, experience during the early years of operation at Oberlin indicated that at least six days of storage were necessary to

* Calgon, Inc., Pittsburgh, Pa.

stabilize the softened water. Even then, the mains slowly filled with scale and changes were made which permitted six weeks storage of the filtered water. Since this change was made, there has been little after-precipitation in the mains, but scale has continued to form in the hot-water heaters. Several years ago, the use of sodium hexametaphosphate* was initiated and this has proved entirely successful in effecting the complete stabilization of the water and preventing scale formation in hot-water heaters.

The degree of stability attained by six days of storage at Oberlin is now attained in a few hours by intimate contact with large quantities of sludge and to a lesser extent by ordinary filtration. It has long been known that such water, though stable in the cold, will precipitate scale upon heating. Study of the Langelier equation also emphasizes the fact that a water in equilibrium with calcium carbonate at low temperatures becomes supersaturated as the temperature increases. Obviously, then, it is impossible to stabilize a lime or lime-soda softened water completely by these methods.

## Recarbonation

The addition of acid ($CO_2$) is the most obvious and was the first chemical treatment used to stabilize lime and lime-soda softened water. Since its first use† there has never been any dispute as to the fact that caustic and normal carbonate alkalinity can be converted to bicarbonate by the addition of carbon dioxide, thus preventing any after-precipitation of calcium carbonate. There has been some discussion as to whether the carbon dioxide should be added before filtration to protect the filter sand from incrustation, or in the clear well only to protect the distribution system and the consumers' piping. The disadvantage of complete recarbonation before filtration is that much of the calcium and magnesium compounds, which are being carried in suspension, is redissolved, while any precipitation which would otherwise take place on the filter sand is prevented, thus producing a harder water. A partial recarbonation ahead of filtration, however, by converting the excess caustic to carbonate, will cause more precipitation in the final sedimentation and on the filter sand and so produce a softer water. At any rate, these distinctions are losing much of their force, since, in the newer plants, very nearly complete reactions are being obtained in the reaction chambers through the recircula-

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* Sodium hexametaphosphate is the name which has commonly been applied to the molecularly dehydrated sodium phosphate glass with the composition $(NaPO_3)_x$. The commercial material known as Calgon is a somewhat more basic glassy sodium phosphate.

† Hill, Nicholas S., Jr. Recarbonization of Softened Water. Jour. A.W.W.A., **11**: 393 (1924).

tion of sludge or through passing the water up through a mass of suspended sludge as mentioned above.

## Corrosion in Hot-Water Heaters

The principal point of discussion has been centered, however, around the cause of, and the remedy for, complaints of corrosion and "red water," which arose in some cities after recarbonation was begun. These were rarely serious in the cold, but frequently developed to an alarming extent in hot-water systems where galvanized tanks were used. Sometimes several years passed after the recarbonation process was started before these complaints began to be numerous; and in other softening plants, using carbon dioxide for stabilization, they have never been reported. Is this because some plants have refused to admit responsibility for corrosion occurring in hot-water tanks or is there something more fundamental involved?

From many discussions on this point, it is the writer's conclusion that, where the source of supply for the plant consists of well water, difficulty with corrosion will probably not be experienced at all and certainly not to an appreciable degree, except under unusual circumstances. This is believed to be due to the fact that aeration to remove carbon dioxide from the water is frequently insufficient to result in the absorption of an appreciable amount of oxygen. Also, since the water in the reaction and sedimentation basins is from 10 to 20 ft. deep, a relatively small surface is exposed and, again, there is very little absorption of oxygen. Consequently, unless there is a large excess of air used in the recarbonation process or prolonged exposure of the water in open clear wells or reservoirs, it will usually be found that the oxygen content of the finished water does not exceed 4 or 5 ppm. Such low concentrations of oxygen do not seem to be sufficient to produce serious troubles with "red water" in hot-water heaters, as shown by the fact that, even in the plants using surface supplies, the difficulty is most pronounced and the complaints most numerous during the winter months, when the temperature of the raw water has dropped and the oxygen concentration is in excess of 8 or 9 ppm.

On the other hand, this trouble with corrosion is to be expected in all plants softening surface water supplies, whether they are rivers, lakes or reservoirs. There may be a lag of several years after recarbonation is begun before trouble develops, probably due to the fact that either hard water or softened uncarbonated water was previously used and a considerable period of time must elapse before old scale is redissolved or a sufficient number of new galvanized iron tanks installed which do not contain old deposits and which may be expected to begin to give trouble from "red water," as soon as the zinc has been removed. Tests made at Columbus,

Ohio, and Dallas, Texas, have indicated that, with a stabilized water of pH approximately 9.3, the galvanized coating in a hot-water tank will ordinarily last less than one year and, since the corrosion tends to take the form of localized pits, failure frequently occurs very soon therafter.

When recarbonation was first used, as Mr. Hoover mentioned in his paper, it was the practice to add sufficient carbon dioxide to change all the alkalinity to the bicarbonate form. In an attempt to overcome the trouble with "red water" experienced when using recarbonation to stabilize surface supplies, however, the amount of carbon dioxide used has repeatedly been decreased. The first reduction was to a point where the water, when heated, was in exact equilibrium with calcium carbonate; next, to the point of calcium carbonate stability at room temperatures. As the complaints continued, it was reduced still more until the water was leaving the plant in such a highly supersaturated condition as to cause serious trouble with deposits in the meters and hot-water heaters. In some plants this meant carrying the pH of the finished water at as high as 11.0 and with more than 20 ppm. of free caustic alkalinity present. In others, soda ash was added to the clear well to increase the carbonate ion concentration beyond that which would remain in solution while passing through the filters. Usually these efforts were unavailing and the trouble with corrosion of hot-water tanks continued.

Although tests made by Mr. Hoover at Columbus on galvanized iron hot-water tanks showed that the galvanizing was largely destroyed in less than one year's time by the stabilized water at a pH of 9.3, they also showed that the uncarbonated water at a pH of approximately 10.2 had coated the galvanizing with a protective layer of zinc oxide, zinc carbonate and calcium carbonate, which, though soft, seemed to be sufficiently homogeneous to afford protection for a number of years. Since no trouble had been experienced with corrosion of galvanized-iron hot-water tanks during the twenty years which the Columbus plant had been operated before recarbonation was started, it was Mr. Hoover's conclusion that, if water of this character were supplied, little or no trouble with the tanks would be experienced and new tanks would last indefinitely. He was forced to conclude, however, that it was impractical to furnish water of this type to the city, because, over a period of years, it would fill the distribution system with scale in addition to shifting the burden of consumer complaints from corrosion and "red water" in hot-water tanks to scale formation in hot-water heater coils.

## Sodium Hexametaphosphate

Faced with this dilemma of corrosion versus scale formation, it is easy to see why the operators of many softening plants saw that treatment with

the molecularly dehydrated phosphates offered a possible solution. Extensive use of these materials had already been made in the treatment of cooling water in various industrial plants, as well as for stabilization of lime-soda softened water in both railroad and stationary power plant service. Its use at Delaware, Ohio,* under the supervision of Mr. Hoover, showed that as little as ½ ppm. of glassy sodium phosphate was sufficient to prevent entirely the after-precipitation of calcium carbonate on filter sand as well as in the distribution system.

As mentioned above, it had been shown at Columbus that the softened and settled, but uncarbonated, water did not attack the galvanizing of hot-water tanks as did the recarbonated water. Consequently, it was decided to recarbonate only to neutralize the caustic alkalinity and to rely on sodium hexametaphosphate for final stabilization. Thus, the character of the water was changed in two important particulars at this time. A fraction of a part per million of metaphosphate was present in the water and, in addition, the water itself was changed from one stable with respect to calcium carbonate and containing both bicarbonate and carbonate alkalinity to one containing only normal carbonate. The first particular may seem relatively unimportant aside from its stabilizing action on calcium carbonate, but it is believed to be of importance also from the standpoint of decreasing corrosion, as will be shown below.

Within a few weeks after this change in the method of stabilizing the Columbus water had been placed in effect, it was noticed, in several hot-water tanks under observation, that the amount of iron oxide which accumulated in the bottom of the tanks had diminished and, during the succeeding months, that the number of complaints of "red water" decreased almost to zero. Everyone concerned was highly pleased with these results. One question still remained unanswered, however: Was the increased pH and carbonate ion concentration responsible or was the phosphate decreasing corrosion as well as stabilizing the water?

Another set of tests on hot-water tanks made in the plant at Columbus over a period of a year gave inconclusive results, since all of those operating on the finished water, whether or not it contained phosphate, showed that the zinc was being protected. Thus, it was certain that new galvanized tanks would be protected; but these experiments did not explain why "red water" had disappeared from old tanks from which much of the zinc had already been removed before the change in treatment was made. To settle this point, another set of tanks, both black iron and galvanized, is under test. This experiment has been under way for more than a year,

* Hoover, Charles P. and Rice, Owen. Threshold Treatment. W.W. & Sew., **86**, 10 (1939).

but since the former run had shown that, with water of the type now being furnished at Columbus, the galvanizing would last for more than a year, it is planned to continue this test for at least six months or a year longer so that, if possible, some indication may be obtained as to whether or not the phosphate itself has some specific effect in protecting the zinc. The water from the black iron tanks is also of surprisingly good quality, so it is felt desirable to continue the test on these tanks for a longer period of time as well.

During the time these observations were being made at Columbus, the use of phosphate glass for stabilizing water from municipal lime-soda softening plants had been started in other plants throughout the country. Several of these had never used recarbonation or had previously discontinued it because of difficulties with operation or control, so that their use of phosphate was not accompanied by any change in the pH or other characteristics of the effluent water. Thus, from plants as far separated as Ohio and California, reports were received that, not only was stabilization achieved, but within a few days or a few weeks after the start of treatment, the "red water" which had previously been noticed in water heaters around the plant had disappeared and within a few months it was evident that complaints from the consumers had virtually ceased.

This encouraged the writer to recommend this treatment at a Texas plant where no trouble had been experienced with scale, but where the corrosion of galvanized iron hot-water tanks had been a particularly serious problem. There, too, no change was made in the pH or other characteristics of the water at the time the use of vitreous sodium phosphate was begun and, even though only $\frac{1}{2}$ ppm. was used, the records showed that, during the next winter, a reduction of 90 per cent was made in the number of complaints received. Also, checks made on various water heaters, both in the plant and in private homes, which had given trouble in previous years showed no "red water" at any time and a great decrease in the amount of sediment withdrawn from the bottom on monthly tests.

During the past three years, the same experience has been reported from many additional lime-soda softening plants which had formerly had trouble due to "red water" in hot-water heaters, and, as a result, the writer is of the opinion that, in addition to stabilizing the normally supersaturated water produced from a lime-soda softening plant, the use of phosphate glass also has an effect in decreasing corrosion in hot-water tanks.

The effectiveness of the molecularly dehydrated phosphates in preventing the precipitation of calcium carbonate from a softened water has been amply demonstrated and little more need be said. Many tests have been conducted and reported in the literature, the most exhaustive prob-

ably being those made by Rogers at Wichita,* where it was shown that as little as ½ ppm. of sodium hexametaphosphate was sufficient to prevent entirely precipitation from the partially softened water, even at temperatures as high as 212°F. Rogers also reported a very pronounced improvement at several restaurants where the water temperature frequently went as high as 220°F.

In short, then, it may be said that lime-soda softened water can be fully stabilized with respect to calcium carbonate both by recarbonation and by the addition to the water of ½ ppm. or more of a molecularly dehydrated phosphate. Where well water is used and it does not pick up more than 4 or 5 ppm. of oxygen through aeration and subsequent exposure recarbonation will be found to be entirely satisfactory.

Where, on the other hand, surface waters are the source of supply or where, through aeration and exposure, well water dissolves more than 8 ppm. of oxygen, it has generally been found that some difficulty with corrosion and "red water" in galvanized hot-water tanks will be experienced when furnishing a water which has been stabilized by recarbonation. The use of phosphate for this purpose, however, will not only prevent the precipitation of calcium carbonate throughout the distribution system and through hot-water heaters, but will also greatly reduce the difficulty being experienced with corrosion in hot-water tanks.

## Magnesium Silicate Scale

From these remarks, it might seem that the problem of stabilizing lime-soda softened water had been entirely solved through the refinement of recarbonation process and the newer development of the use of glassy sodium phosphate. Mr. Hoover has been frank enough to admit that he thought recarbonation the complete answer to this problem in 1927, so the writer will be equally frank in admitting that ten years later he thought 1 part per million or so of phosphate was the complete answer. Unfortunately, this is not quite true. Some difficulty is still being experienced in a few cities, despite this treatment, with the formation of soft deposits of magnesium silicate in hot-water heaters which are operated at temperatures above 160°F. Fortunately, the occurrence of these deposits has not been widespread.

In the first place, it should be made clear that a careful study, by means of both the polarizing microscope and the x-ray, of samples from many localities indicate that a definite compound is involved, a hydrated magnesium silicate ($3MgO \cdot 2SiO_2 \cdot 2H_2O$). The deposition of magnesium silicate following lime-soda softening in the past seems to have gone unnoticed

* Rogers, M. E. Operation Problems in the New Wichita Water System. Jour. A.W.W.A., **33:** 1233 (1941).

because it did not take place in the cold, that is, on filter sand or in the distribution system, nor in hot-water heaters operated at normal temperatures. It did precipitate along with calcium carbonate in hot-water heaters operated at relatively high temperatures, but, since calcium carbonate still formed about 90 per cent of the deposit, it was overlooked or disregarded and the attention of water works men concerned with stabilization was centered on calcium carbonate which still remained the greatest offender. The exception to this rule seems to have been Topeka, Kan., where the deposition taking place in hot-water heaters was composed almost entirely of hydrous magnesium silicate. Frankly, when this finding was brought to his attention, the writer could scarcely believe that no carbonate was present.

As was pointed out, this condition at Topeka seems to have been alleviated by treatment with only $\frac{1}{4}$ ppm. of sodium hexametaphosphate. Nevertheless, some complaints due to trouble of this sort continue to be received from other plants where phosphate is being used for stabilization, so that this alone does not seem to be a complete answer to the problem. In all cases, however, it has been noticed that, where the trouble is persistent, the temperatures are excessive; and it has been generally found that, by keeping the water temperature below 160°F., such deposits can be practically eliminated.

Experience at various plants indicates that the magnesium and silica concentrations must be kept at very low values, possibly below 5 ppm. of each, to prevent subsequent deposition in hot-water heaters which are operated at excessive temperatures. Alternatively, it has been found necessary to lower the pH of the plant effluent to approximately 8.8—usually below the calcium carbonate stability point—to prevent deposition of magnesium silicate at temperatures above 160°F. It is apparent that recarbonation to such a low pH value will be a feasible remedy for trouble of this nature if a well water supply is used, but it is not a practicable one with surface supplies, because of the probability that there would then be far more trouble with corrosion than would otherwise take place due to the deposition of magnesium silicate.

What this means in practice is that, with waters carrying considerable magnesium and silica, treatment with lime only to the extent of the bicarbonate hardness is not sufficient, since this leaves the remaining magnesium in an unstable condition. Excess lime and a heavy dose of coagulant should be used to reduce the magnesium and silica to the lowest possible figure and this should be followed by recarbonation to neutralize the caustic alkalinity and to cause the maximum precipitation of the calcium and, preferably, final stabilization with phosphate.

In passing it should be pointed out that no magnesium silicate in water heaters has been encountered where the water has not been treated with

lime. Hard waters, or waters partially softened with zeolite, precipitate a scale that is almost pure calcium carbonate. This can be entirely eliminated by the use of phosphate. Here, of course, the pH will always be well below the maximum limit of 8.8, where the magnesium silicate seems to become unstable at elevated temperatures.

## Conclusions

1. Long storage or filtration through sludge blankets will give a water stable at room temperatures, but unstable when heated.

2. Recarbonation to the "stability point" or "0" Langelier index will produce a water stable in the cold, but supersaturated with calcium carbonate at elevated temperatures.

3. Recarbonation to a point below the room temperature "stability point" or to a slight negative Langelier index will prevent the precipitation of calcium carbonate when the water is heated.

4. Stabilization by means of recarbonation will prove satisfactory if the finished water contains less than 4 or 5 ppm. of oxygen.

5. Trouble due to corrosion and consequent "red water" is to be expected in hot-water tanks wherever the oxygen content of the finished water exceeds 8 ppm., when recarbonation is carried to the point of complete stabilization.

6. The molecularly dehydrated phosphates will prevent the precipitation of calcium carbonate, even at high pH values, carbonate ion concentrations and temperatures.

7. The presence of 1 or 2 ppm. of molecularly dehydrated phosphates decreases trouble with "red water" in hot-water tanks due to specific corrosion-inhibiting properties of the phosphate, to the fact that a higher carbonate ion concentration is maintained, or to the combination. Where water carrying more than 8 ppm. oxygen is used, recarbonation should not be carried to the point of final stabilization, but should cease when the hydroxide has just been converted to carbonate alkalinity, phosphate being added for final stabilization.

8. Deposits of hydrated magnesium silicate ($3MgO \cdot 2SiO_2 \cdot 2H_2O$) will form at temperatures above 160°F. at pH values above 8.8 in waters carrying more than about 5 ppm. of magnesium and 5 ppm. of silica.

9. Some reports indicate that deposition of hydrated magnesium silicate is decreased by the addition of 1 ppm. or less of glassy phosphate.

10. To minimize trouble from magnesium silicate deposits in waters carrying more than 8 ppm. oxygen, excess lime treatment along with alum should first be used, to effect a maximum removal of magnesium and silica. This should be followed by recarbonation to a pH of 9.6–10.0, converting all or nearly all of the hydroxide to carbonate; and final stabilization should be secured by addition of glassy sodium phosphate.

# ABSTRACTS OF WATER WORKS LITERATURE

**Key, 31:** 481 (Mar. '39) indicates volume 31, page 481, issue dated March 1939, If the publication is paged by issues, **31:** 3: 481, (Mar. '39) indicates volume 31. number 3, page 481. Initials following an abstract indicate reproduction, by permission, from periodicals as follows: *B.H.—Bulletin of Hygiene (British); C.A.—Chemical Abstracts; P.H.E.A.—Public Health Engineering Abstracts; W.P.R.—Water Pollution Research (British); I.M.—Institute of Metals (British).*

## CHEMISTRY

**The Estimation of Metals in Water, With Special Reference to the Use of Organic Reagents.** Thomas Stones. Wtr. & Wtr. Eng. (Br.) **44:** 115 (May '42.) *Ferric Iron:* (1) Thiocyanate Method depends on production of ferric thiocyanate by action of ferric salt and alkali thiocyanate:

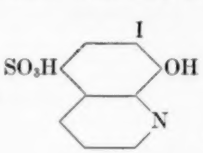
$$Fe_3 + 3KCNS \rightleftharpoons Fe(CNS)_3 + 3KCl$$

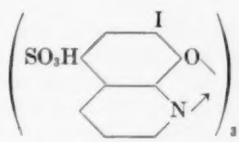
$$Fe(CNS)_3 + 3KCNS = K_3[Fe(CNS)_6]$$

Action reversible and excess of thiocyanate must be present. 0.02 ppm. Fe detectable. (2) Ferrocyanide Method: Potassium ferrocyanide produces in neutral or acid solns. of ferric salts intense blue precipitate of ferric ferrocyanide:

$$3K_4\,[Fe(CN)_6] + 4FeCl_3 = Fe_4\,[Fe(CN)_6] + 12KCl$$

Blue tint discernible when iron content exceeds 0.1 ppm. (3) 7-Iodo-8-Hydroxyquinoline-5-Sulfonic Acid Method: Organic reagent, "Ferron," may be employed for colorimetric estn. of ferric iron with which stable green coloration produced. Intensity varies with quant. of ferric iron present. Reaction not given by ferrous iron. Following course indicated:

$FeCl_3 + 3$ 

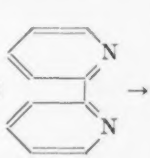
$\rightleftharpoons$  $Fe + 3HCl$

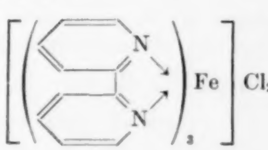
*Ferrous Iron*: (1) Ferricyanide Method: Potassium ferricyanide added to soln. of ferrous salt produces blue coloration of ferrous cyanide mixed with potassium ferric ferrocyanide:

$$2K_3\,[Fe(CN)_6] + 3FeCl_2 = 6KCl + Fe_3\,[Fe(CN)_6]\,2$$

$$K_3\,[Fe(CN)_6] + FeCl_2 = KFe^{+++}[Fe(CN)_6]^{----} + 2KCl$$

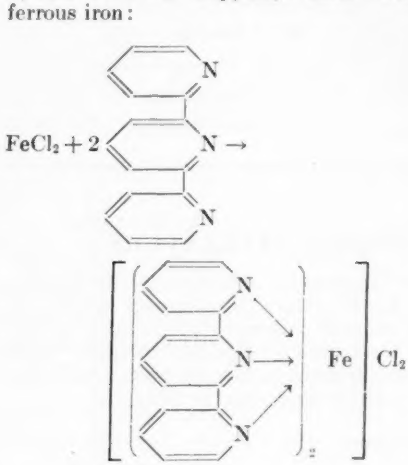
(2) $a - a'$ Dipyridyl Method: Yields salt possessing intense red color which has proved sensitive and specific test for ferrous iron:

$FeCl_2 + 3$  $\rightarrow$

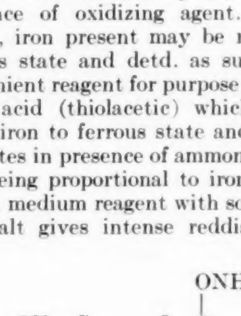


Even more intense colorations, resembling potassium permanganate, displayed

by bis $a-a'-a''$ tripyridyl salts with ferrous iron:



These compds. successfully applied to detn. of iron in sea water. *Total Iron*: This may be estd. by ensuring that all iron is in ferric state by first evapg. in presence of oxidizing agent. Alternatively, iron present may be reduced to ferrous state and detd. as such. Most convenient reagent for purpose is thioglycollic acid (thiolacetic) which reduces ferric iron to ferrous state and then coordinates in presence of ammonia, coloration being proportional to iron present. In alk. medium reagent with soln. of ferrous salt gives intense reddish purple color:



Strong bases dischg. color. Therefore necessary to use ammonia. *Copper*. (1) Ammonia Method: On adding ammonia to a cupric salt, green ppt. of basic salt obtained soluble in excess forming azure blue soln. of cuprammonium sulfate.

$$2CuSO_4 + 2\,NH_4OH = (NH_4)_2SO_4 + Cu_2(OH)_2SO_4$$

$$Cu_2(OH)_2SO_4 + (NH_4)_2SO_4 + 6NH_3 = 2([Cu(NH_3)_4]SO_4 \cdot H_2O)$$

(2) Ferrocyanide Method: Depends on fact that in neutral or acid solns. potassium ferrocyanide produces, with trace of copper, reddish-brown coloration of cupric ferrocyanide.

$$2CuSO_4 + K_4Fe(CN)_6 = K_2SO_4 + Cu_2Fe(CN)_6$$

(3) Potassium Ethyl Xanthate Method: Based on fact that alkali xanthates interact with cupric salts giving yellow coloration of cuprous xanthate, intensity of which is proportional to copper present. Cupric xanthate first formed which splits off dixanthogen, leaving yellow cuprous xanthate:

$$2NaS{-}\overset{\overset{\large S}{\|}}{C}{-}OC_2H_5 + Cu^{++} \rightarrow 2Na^+ + Cu\left(S{-}\overset{\overset{\large S}{\|}}{C}{-}O2_2H_5\right)_2$$

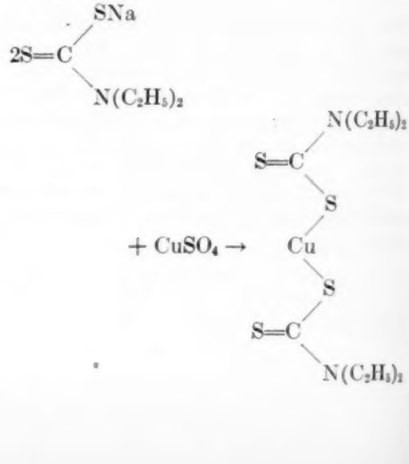
$$2Cu\left(S{-}\overset{\overset{\large S}{\|}}{C}{-}OC_2H_5\right) \rightarrow Cu_2\left(S{-}\overset{\overset{\large S}{\|}}{C}{-}OC_2H_5\right)_2 + \left(S{-}\overset{\overset{\large S}{\|}}{C}{-}OC_2H_5\right)_2$$

Cuprous xanthate Dixanthogen

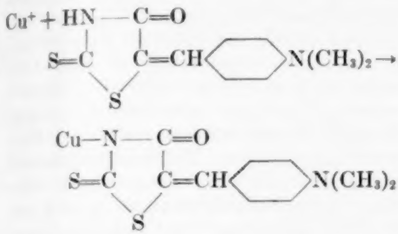
(4) Dithio-Oxamide (Rubeanic Acid) Method: When alc. soln. of dithio-oxamide added to soln. contg. copper characteristic greenish-brown color produced.

$$CuSO_4 + \begin{matrix} NH_2{-}C{=}S \\ | \\ NH_2{-}C{=}S \end{matrix} \rightarrow \begin{matrix} NH{=}C{-}S \\ | \\ NH{=}C{-}S \end{matrix}\!\!>\!Cu$$

(5) Sodium Diethyl Dithiocarbamate Method: White crystalline substance, readily soluble in water, and gives brown ppt. or coloration of normal copper salt of diethyldithiocarbamic acid with solns. contg. copper:

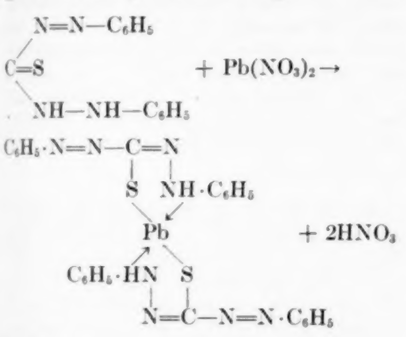


(6) *p*-Dimethylaminobenzylidine Rhodanine Method: Substance reacts with cuprous and cupric copper to form colored salts. Reaction more sensitive in case of cuprous copper. In dilute acid, violet coloration obtained. Hence, copper first reduced to cuprous state by means of hydrazine sulfate and ammonia.

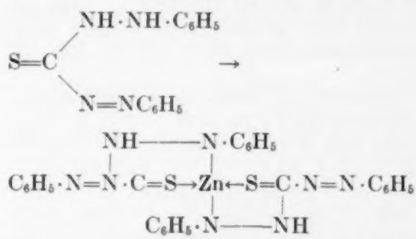


(7) Method of Clark and Jones: Certain oxidizing agents, when added to very dilute feebly alk. solns. of cupric salt contg. dimethyl glyoxime, produce intense reddish violet color resembling permanganate. Clark and Jones employ as oxidizing agent ammonium persulfate with pyridine. Chlorides must be absent. Lead in water may be detd. colorimetrically as sulfide in acetic acid soln.: $H_2S + Pb(NO_3)_2 = 2HNO_3 + PbS$.

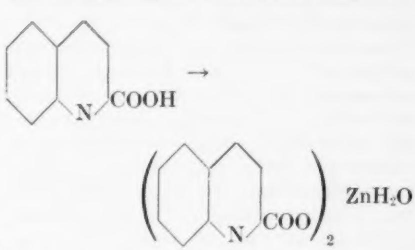
Diphenylthiocarbazone (Dithizone) forms complexes with many metals which dissolve in chloroform or carbon tetrachloride to form typically colored solns. Potassium cyanide inhibits reaction with all heavy metals except lead, thallium and bismuth. Lead complex dissolves in chloroform or carbon tetrachloride to give red color, reaction being:



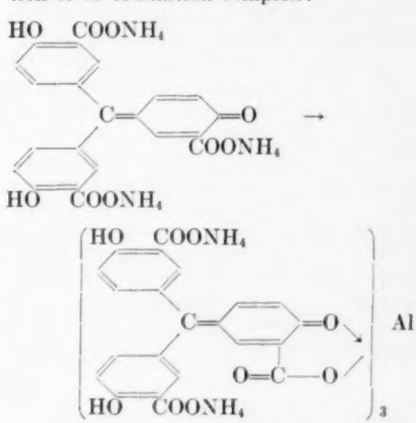
Reagent will detect 0.05 ppm. Pb. Zinc in water usually detd. by pptn. as ferrocyanide and comparing turbidity produced with stds. similarly treated: $2ZnSO_4 + K_4[Fe(CN_6)] = Zn_2[Fe(CN)_6] + 2K_2SO_4$. Allport and Moon detd. zinc in water by extraction, along with other heavy metals, with dithizone in chloroform from alk. tartrate soln. contg. resorcinol. Zinc complex formed thus:



Metals extracted from chloroformic soln. of dithizone by means of $N/10$ HCl and heavy metals removed with $H_2S$ and filtering. Filtrate evapd. to dryness and Zn pptd. by means of quinaldinic acid. Zn as quinaldinate may then be detd. colorimetrically or microchemically:



Aluminum liable to occur in traces in potable waters owing to use of alum and sodium aluminate as coagulants. Most reliable reagent for colorimetric detn. of Al is ammonium aurin tricarboxylate with which it gives a red lake, owing to production of co-ordination complex:



Interference arises from presence of alk. earths, phosphates and iron, but with exception of iron interference can be elimd. by addn. of ammonium carbonate. Reaction best carried out in soln. of pH 6.3, which can be attained by addn. of strong soln. of ammonium acetate after acidification with HCl.—*H. E. Babbitt.*

**$\beta$-Resorcylic Acid as a Colorimetric Reagent for Ferric Iron.** Jean L. Larner and Wm. E. Trout, Jr. Virginia J. Sci. **3:** 1:13 ('42). 2-4-Dihydroxybenzoic acid forms red complex with ferric iron. Transmission curve shows peak between 425 and 450 m$\mu$ with max. in the red. Optimum pH is 2.5–3.0. Under Yoe Roulette Comparator, 1 part in $20 \times 10^6$ can be detected. Several salts interfere with color formation.—*C.A.*

**Development of Method for Determination of Tungsten in Ores.** Antoinetta de Larmo Cantiçao. Inst. Nacional de Technologia (Brazil) Bul. No. 72 ('41). Usual procedures for tungsten detn. unsatisfactory because of large errors introduced as a result of operations involved in sepn. of element from interfering substances. Method developed is based on fact that in presence of oxalate ions tungsten can be quantitatively pptd. by 8-hydroxyquinoline. The oxalate prevents co-pptn. of interfering ions, principally $Sn^{++++}$, which remains in soln. as complex ion and is therefore easily removed from ppt. by filtration. Method particularly well adapted to anal. of Brazilian tungsten ores which are usually found together with cassiterite (tin stone).—*J. M. Sanchis.*

**Electrolytic Iron as a Standard for the Colorimetric Determination of Iron.** J. E. Lindsay. Chem. Analyst **31:** 1:8 (Feb. '42). Intensity of color in detn. of Fe as ferric thiocyanate extremely dependent upon compn. of soln. Test soln. and std. should therefore be identical in compn. and concn. Numerous substances interfere with reaction, including phosphates, sulfates, chlorides, arsenates, etc. Electrolytic Fe contains negligible amts. of such interfering substances and is most suitable as a std. 20-mesh powd. form used by author. Dissoln. rate very rapid and can be weighed conveniently. Method for detg. Fe in glass sand described.—*R. E. Thompson.*

**Rapid Determination of Sodium in Waters and Soil Extracts.** D. R. McCormick and W. E. Carlson. Chem. Analyst. **31:** 1:15 ('42). Detn. of sodium in waters and soil extracts by gravimetric method of Barber and Kolthoff modified for sufficient accuracy with greatly increased speed and minimal cost of reagents. Advantage taken of fact that water soln. of sodium uranyl zinc acetate absorbs blue light (4000–4650 Å.) to deg. directly proportional to amt. of sodium present in sample. This easily measured using photoelec. colorimeter with blue filter corresponding to above wave band. Further advantage that samples contg. considerable amts. of calcium sulfate may be evapd. to dryness and sodium detd. colorimetrically without interference of calcium sulfate, which, when present to excess, somewhat insoluble in reagent and may be weighed as part of ppt. in gravimetric method. *Procedure.* Evap. to dryness vol. of water or soil extract (filtrate from 50 g. soil in 500 ml. water, allow to stand overnight) contg. not more than 1 mg. sodium and add 10 ml. of Barber and Kolthoff uranyl zinc acetate reagent. Allow to stand 1 hr., transfer quantitatively to centrifuge tube and centrifuge. Pour off reagent completely and wash ppt. in centrifuge tube with 15 ml. of 95% alcohol. Recentrifuge, drain off alcohol completely, dissolve sodium uranyl zinc acetate in water, dilute to 10 ml. and det. concns. in photoelec. colorimeter previously calibrated with known amts. of sodium. May be necessary to centrifuge water soln. of sodium uranyl zinc acetate before reading in colorimeter. Blank detn. made using all reagents. Method found especially suitable when accuracy greater than 5% not necessary.—*Ed.*

**Determination of Ammonia in Water.** I. G. Lakomkin. Lab. Prakt. (U.S.S.R.) **16:** 4: 17 ('41). Treat sample with 50% Seignette salt soln. or with NaOH and $Na_2CO_3$ solns.; to portion add measured quantity of std. $NH_4Cl$ soln. and compare in colorimeter with portion to which $NH_4Cl$ has not been added, after adding Nessler reagent, mixing and letting stand

for 10 min. The $NH_3$ content of sample is $am/(n - m)$, where $m$ is height or vol. of soln. to which $NH_4Cl$ was added, $n$, height or vol. of soln. without $NH_4Cl$ addn., and $a$, amt. of $NH_3$ added to one cylinder. Proposed method and equation can be used in other colorimetric detns., such as detn. of $HNO_2$ according to Griess. Prepn. of colorimetric std. from sample to be examd. effects better matching of colors than does prepn. of std. from distd. water.—*C.A.*

**A Qualitative Method for Nitrogen in Water Analyses.** PAUL H. HORTON. Chemist Analyst **31:** 39 (May '42). 500-ml. sample digested with 5 ml. N-free concd. $H_2SO_4$ with, if necessary, addn. of 5 g. anhyd. $Na_2SO_4$ or $K_2SO_4$, digestion being continued until liquid clear and vol. reduced to about 50 ml. Soln. cooled to room temp., 0.5 g. Devarda's alloy added, and, with flask slightly inclined, 30 ml. 1:1 NaOH introduced slowly down side of flask to form layer below acid soln. Flast connected to spray trap and glass condenser, with delivery tube from latter extending into small quant. of Nessler's soln. (conveniently, 30 ml. water to which has been added 2 ml. Nessler's soln.), agitated, and allowed to stand 30 min. with or without heating or with very small flame, depending upon intensity of reaction between alloy and alkali, and then heated until 50 ml. distillate collected. Free $NH_3$ and org. nitrogenous matter converted to ammonium acid sulfate by digestion, while $NO_3^-$ and $NO_2^-$ are reduced to $NH_3$ by alloy. If absence of N indicated by failure to obtain characteristic color reaction with Nessler's soln., tests for specific forms of N may be dispensed with. Otherwise, tests for $NH_3$, albuminoid N, org. N, $NO_3^-$ and $NO_2^-$ should be conducted.—*R. E. Thompson.*

**A New Stabilizing Agent for Nesslerized Solutions. Its Application to the Determination of Urea Nitrogen in Biological Fluids.** JAMES HUGHES AND ABRAHAM SAIFER. J. Lab. Clin. Med. **27:** 391 ('41). One drop of 2% soln. of liquoid (Na polyanetholesulfonate) prevents clouding of 10-ml. vol. of Nesslerized soln. Transmission values (photoelec. colorimetry) of solns. so stabilized fall much more slowly than those of solns. contg. gum ghatti, gum arabic or gum senegal. Liquoid gives very low blanks and is obtainable in pure form (Hoffman-La Roche product). Use in analysis of biol. fluids described.—*C.A.*

**Determination of Nitrites.** N. F. KERSHAW AND N. S. CHAMBERLIN. Ind. Eng. Chem.—Anal. Ed. **14:** 312 (Apr. '42). Adaptation of Shinn method to water anal. For convenience, 50- or 100-ml. samples taken instead of 35 ml., and compared with series of stds. in matched Nessler tubes instead of using photoelec. or Dubosq colorimeter. Ammonium sulfamate reagent eliminated as unnecessary. 2 ml. of 0.5% sulfanilamide in 1 to 1 HCl used instead of separate solns. of the 2 reagents. *N*- (1-naphthyl)-ethylenediamine dihydrochloride used as coupling agent as recommended by Shinn. Soln. thoroughly mixed after addn. of each reagent. Color reaches max. in 15 min.; more rapid and more stable than Shinn method. Stds. prepd. from desiccated reagent grade sodium nitrite. Modification reported increases sensitivity from 0.015 to 0.001 ppm. nitrite N, making range comparable to present std. method. —*Selma Gottlieb.*

**Color Analysis and Colorimetry.** *I. Nitrate Estimation.* G. V. L. N. MURTY. Proc. Indian Acad. Sci. **14A:** 43 ('41). Study of brightness, dominant wave length and purity of tests with $\alpha$-naphtholsulfonic acid and with phenolsulfonic acid shows that with same nitrate content, former reagent gives colors with longer dominant wave length and with greater brightness. With low concns. of nitrate, phenolsulfonic acid reagent gives colors with high brightness. Not entirely satisfactory for concns. contg. less than 1 mg. nitrate N; with such low concns., $\alpha$-naphtholsulfonic acid test is better. With higher concns., conditions reversed. Two tests therefore complementary, each being efficient in its own field of concn.—*C.A.*

**Ferric Chloride as a Permanent Standard in the Colorimetric Estimation of Nitrate.** G. V. L. N. MURTY. Proc.

Indian Acad. Sci. **13A:** 116 ('41). In detg. nitrate with $\alpha$-naphtholsulfonic acid, color not permanent for more than 6 hr. An 0.08 *N* ferric chloride soln., however, has exactly same color as soln. contg. 0.25 mg. nitrogen as nitrate; this suggests use of ferric chloride soln. as permanent std. Tests with 0.1, 0.2, 0.3, 0.4 and 0.5 mg. nitrogen entirely satisfactory.—*C.A.*

**Colorimetric Determination of Nitrate With $\beta$-Methyl-Umbelliferone.** A. S. Vasil'ev and M. M. Dukhinova. Zavodskaya Lab. (U.S.S.R.) **10:** 35 ('41). Method for colorimetric detn. of nitrate described in which 0.3 ml. of sample placed in 10-ml. pycnometer, 0.6 ml. $\beta$-methyl-umbelliferone added, and soln. thoroughly mixed. Pycnometer kept in boiling water for 3–5 min.; contents then diluted with water and sufficient ammonia soln. added to make mixt. alk. Soln. dild. to mark with water and compared in Dubosq colorimeter with std. subjected to similar treatment. Lemon-yellow color obtained stable for several weeks and follows Lambert-Beer law. Procedure takes about 15 min. and may be used to det. up to 0.5$\gamma$ with accuracy of $\pm$ 1%. Addn. of 0.5 ml. of 0.03% Safranin per 10 ml. soln. changes color to yellow-pink which is more easily evaluated, and is stable for several days. Of various light filters tested, best results obtained with 20% copper sulfate soln.—*C.A.*

**A New Micromethod for the Determination of Nitrates in Drinking Waters.** D. B. Iokhel'son. Lab. Prakt. (U.S.S.R.) **16:** 4: 19 ('41). Method consists of converting salicylic acid to picric acid in $H_2SO_4$ soln. by nitration and colorimetric comparison of Na picrate with std. Reaction is $3HNO_3+C_6H_4(OH)COOH = C_6H_2(NO_2)_3OH+3H_2O+CO_2$. Sensitivity of reaction 0.002 mg. of $N_2O_5$. Pour 1 ml. of sample into 25-ml. beaker, add 0.05 ml. (2–3 drops) of alc. salicylic acid (10% salicylic acid in 95° alc.), 1 ml. of concd. $H_2SO_4$ (density, 1.84), shake and add 10 ml. clear NaOH soln. (15:100, density 1.168–1.172). In presence of nitrates yellowish green color obtained. Compare this with stds. contg. from 5 mg. to 100 mg. of $N_2O_5$ in 100 ml. Std. solns. can be kept indefinitely in dark in test tubes with ground stoppers. Nitrite, chloride and carbonate do not interfere.—*C.A.*

**Phosphate Determination by the V. Lorenz Procedure.** Yvonne E. Stourdzé. Inst. Nacional de Tecnologia (Brazil) Bul. No. 73 ('41). Advantages of the Lorenz method over others in use are simplicity and ability to diminish effect of interfering substances in rapid detn. of phosphates. Reagents required follows: (1) Sulfated Ammonium Molybdate. Place 100 g. ammonium sulfate in 2-l. volumetric flask, add 1 l. of nitric acid (sp. gr. 1.36) and agitate flask until sulfate goes into soln. Dissolve 300 g. ammonium molybdate in hot water, cool to 20°C. and make up to 1 l. Add molybdate soln. slowly to ammonium sulfate-nitric acid mixt. while maintg. content of flask in constant agitation. Allow to stand 48 hr. at room temp. and filter. Reagent kept in cool, dark place. (2) Nitric Acid (sp.gr. 1.2). (3) Nitric-Sulfuric Acid Mixt. Mix 30 ml. sulfuric acid (sp.gr. 1.84) and 1 l. nitric acid (sp.gr. 1.2). Calcium phosphate, superphosphates, manures, etc., prepd. as follows: *Water soluble phosphates*: For superphosphates, 20 g. of material extracted in water and soln. made up to 1 l. Take 10 ml. aliquot for detn. For double superphosphates, extract 10 g. of material with water and make up to 1 l. Take 10 ml. aliquot for detn. *Ammonium citrate soluble phosphates:* For Thomas slag, extract 10 g. of material with 1 l. of aq. soln. contg. 25 g. citric acid and 1 g. salicilic acid. Take 15 ml. aliquot for anal. For superphosphates, extract 20 g. of material in 1 l. of reagent prepd. by dissolving 500 g. of citric acid in 700 ml. of ammonia (sp.gr. 0.91), cooling soln. to 15°C., adding distd. water at 15°C. until sp.gr. of reagent is 1.09, adding 50 ml. of ammonia (sp.gr. 0.91) per l. of soln., allowing to stand 48 hr., and filtering. Take 10 ml. aliquot for pptn. (4) Total Phosphoric Acid: For superphosphates or Thomas slag, (a) treat 5 g. of material with 35 ml. of concd. sulfuric acid (with or without addn. of few ml. nitric acid); or (b) treat 5 g. of substance with 100 ml.

of nitric acid. In either case, dil. extract to 500 ml. and take 15 ml. aliquot for detn. For bone powder and mineral phosphates, pptd. phosphates, double phosphates, guano, manures, etc., contg. more than 10% phosphoric acid, (a) treat 5 g. of material with 50 ml. concd. sulfuric acid (with or without addn. of few ml. nitric acid); or (b) treat 5 g. of material with 100 ml. nitric acid. In cases a and b, dil. to 500 ml. with water and take 10 ml. aliquot for test. For pulverized horn and manures with less than 10% phosphoric acid, attack 10 g. of material with 50 ml. of sulfuric acid or, if resulting soln. too dark, with 50 ml. of sulfuric and few ml. of nitric acid. Make up to 500 ml. and take 15 ml. for anal. For arable soils and similar materials contg. less than 1% phosphoric acid, treat 25 g. of material with not more than 200 ml. of nitric acid, sp.gr. 1.2; add 200 ml. of water; cool and add 10 ml. of concd. sulfuric acid; make up to 500 ml. with distd. water and take 50 ml. for anal. To ppt. the phosphates, place prepd. aliquots in 250 ml. beakers. If attack made with sulfuric acid, add necessary amt. of reagent 2 to obtain a 50-ml. vol. of combined aliquot and reagent. If material treated with nitric acid, add enough reagent 3 to obtain combined vol. of 50 ml. Soil extract aliquots already of proper vol. and contain suitable quants. of nitric and sulfuric acids. Bring prepd. aliquots to boiling, remove from fire, agitate few seconds, and add 50 ml. of reagent 1 from burette. Cover soln., allow ppt. to settle for 5 min., agitate for 30 sec. allow to stand from 2 to 18 hr. (not less than 12 hr. if the aliquot contains less than 3 mg. of $P_2O_5$), and filter through previously weighed Gooch crucible. Wash ppt. with a 2% ammonium nitrate soln. and dry by washing 3 times with alcohol and twice with ether. Allow crucible to stand in a vacuum desiccator (100 to 200 mm. pressure) during 30 min., and weigh rapidly. Phosphomolybdate ppt. thus obtained contains 3.295% $P_2O_5$. Instead of detg. phosphates gravimetrically, author prefers following volumetric method suggested by F. Scheffer. Transfer ppt. to Gooch crucible after several rinsings and decantations with 1% sodium sulfate soln. Continue washing until filtrate ceases to give acid reaction with litmus paper. Dissolve ppt. with known vol. of $N/10$ sodium hydroxide soln. (25 to 50 ml.) receiving soln. in beaker in which pptn. made and wash crucible in cold water. Add 5 ml. of a soln. (neutral to phenolphthalein) contg. 1 g. of phenolphthalein dissolved in 1,500 ml. of formalin. Titrate immediately with $N/10$ hydrochloric acid. If,

$a$ = ml. of $N/10$ NaOH added and,
$b$ = ml. of $N/10$ HCl needed to neutralize excess NaOH

$(a - b)\ 0.2537$ = mg. of $P_2O_5$ in aliquot analyzed.

For larger quants. of phosphate, use of stronger concn. of acid and hydroxide ($N/5$ or $N/2$) advocated. Suggestions for the application of Lorenz method to the detn. of phosphates in iron and magnesium ores, and in aluminum, iron and manganese phosphate rocks, etc., given and difficulties usually encountered in this type of anal. described. Method has been found to yield accurate results when aliquot taken for anal. contains from 0.1 mg. to 50 mg. $P_2O_5$. Limiting concn. of common interfering substances as follows: chloride, 0.5 g.; silica, 0.01 g.; citrates, 1 g.; ammonium salts of any type, 1 g.; calcium carbonate, 0.5 g.; aluminum oxide, 0.5 g.; iron oxide, 0.5 g.; and manganese carbonates, 0.5 g.—*J. M. Sanchis.*

**Convenient Colorimetric Test for Phosphates in Boiler Water.** GEORGE A. JOHNS. Power. **86:** 112 ('42). Ammonium phosphomolybdate formed by addn. of $H_2SO_4$ soln. of ammonium molybdate, reduced by *p*-methylaminophenol sulfate and color stabilized by 1.67 $N$ NaOAc soln. Interference from $SiO_2$, $Cl^-$, $SO_4^{--}$, $CO_3^{--}$ and OH negligible, color stability good and error can be held within 1% with concn. of phosphate as low as 10 ppm. in presence of silica concns. as high as 1,000 ppm.—*C.A.*

**Rapid Turbidimetric Method for Determination of Sulfates.** JOSEPH F. TREON AND W. E. CRUTCHFIELD JR. Ind. Eng. Chem.—Anal. Ed. **14:** 119 (Feb. '42). Method developed for urine depends on pttn. with 20- to 30- mesh cryst. $BaCl_2$ in soln. contg. HCl, reading resulting suspension in spectrophotometer,

photoelec. colorimeter or Duboscq colorimeter. If aq. soln. of $BaCl_2$ used, suspension not lasting, and results very low and inconsistent. Std. curve prepd. for instrument used.—*Selma Gottlieb.*

**Perchloric Acid Oxidation of Organic Phosphorus in Lake Waters.** Rex J. Robinson. Ind. Eng. Chem.—Anal. Ed. **13:** 465 (July '41). Dissolved phosphorus in lake water utilized by growing phytoplankton. Most of total P organically bound and must be released by oxidation of org. matter before detn. of total P. Oxidation with $HClO_4$ to be preferred to use of $H_2SO_4$ and $HNO_3$ because of simplicity and convenience. To 100-ml. water sample in 125-ml. Erlenmeyer flask, add 0.2 ml. (or more in hard waters) of 72% $HClO_4$ and evap. to acid fumes. If oxidation slow, cover flask with watch glass to prevent loss of acid, and heat until color disappears. Before applying Denigés colorimetric method for total P, titrate excess acid carefully with $N$ $NH_4OH$ just to alk. color of methyl red or phenolphthalein followed by $N$ HCl just to acid color of indicator. Using photometer, color of methyl red may be compensated for; when phenolphthalein is used, color comparisons may also be made in Nessler tubes.—*Selma Gottlieb.*

**Detection of Carbon Dioxide and Sulfur Dioxide From Mixtures of Carbonates and Sulfites.** G. B. Heisig and Aaron Lerner. Ind. Eng. Chem.—Anal. Ed. **13:** 843 (Nov. '41). If gas contg. small amt. of $SO_2$ and $CO_2$ passed through few drops acid soln. ferric ferricyanide, $SO_2$ will be oxidized to non-volatile bisulfate ion; brown ferric ferricyanide will be reduced to Turnbull's blue; and $CO_2$, passing through the liquid, detected with barium hydroxide without interference. Simple apparatus and procedure described for test on semimicro scale.—*Ralph E. Noble.*

**Determination of Dietary Fluorine.** J. F. McClendon and W. C. Foster. Ind. Eng. Chem.—Anal. Ed. **13:** 280 ('41). Microchem. method for detn. of fluorine based on coloration produced in presence of a thorium salt and alizarin. Thorium-alizarin-fluorine interaction studied spectrophotometrically, detg. pH with glass electrode. From absorption curve obtained, concluded that method for detn. of fluorine depends on change in ionization const. of alizarin produced by thorium. Change in dissociation of alizarin and of alizarin-thorium plotted against change in pH. Data indicate that thorium soln. should be standardized at exact pH value, ionic strength and temp. at which fluoride titrated. pH should be $\gtrdot$ 3.5 and $\lessdot$ 3.0, since reduction of pH causes reduction in intensity of color and consequently in sensitivity of method. Presence of sodium ion interferes with reaction, owing possibly to formation of $ThF_4 \cdot NaF$ and to change in ionic strength. Open ashing of sample leads to loss of chloride and possibly to loss of fluoride, since potassium chloride and potassium fluoride have same temp. of sublimation. Method therefore evolved for burning samples completely in a closed combustion train without loss of fluorine. After ashing, sample steam-distd. with perchloric acid in specially designed micro-still on oil bath at 150°C. Acidity of distillate kept as low as possible by efficient trap and by addn. of sodium sulfate or perchlorate to distg. flask. pH value of distillate adjusted by addn. of perchloric acid or caustic soda, aq. sodium alizarin sulfonate added, and appropriate titre of thorium soln. run in to give required color matched with soln. from blank distillate. Back titration on blank distillate used to correct for any fluorine in reagents used. Titrations and detns. of pH value made in cellophane chamber thermostatically controlled at 25°C. Combustion train, prepn. of reagents, and the micro-still fully described and detailed acct. given of process. Results for content of fluorine of 2.5 to 10.0 micrograms accurate within 5% and for 1 microgram within 7%. Method applied to recovery of fluorine from teeth and bones of rats fed on diet contg. known quants. of fluorine.—*W.P.R.*

**Determination of Small Quantities of Fluoride in Water.** William L. Lamar and Charles G. Seegmiller. Ind.

Eng. Chem.—Anal. Ed. **13:** 901 (Dec. '41). Zirconium-alizarin method modified to facilitate convenient and accurate detn. of small amts. F in large no. water samples. Sulfuric acid used to acidify latter to reduce sulfate interference. pH accurately controlled to give most sensitive comparisons. Most natural waters can be anald. by modified procedure without resort to correction curves. F content of waters contg. less than 50 ppm. sulfate, 500 ppm. bicarbonate and 1,000 ppm. chloride may be detd. within 0.1 ppm. when 100-ml. sample used.—*Ralph E. Noble.*

**Removal of Fluorides From Public Water Supplies.** R. C. Goodwin and James B. Litton. Ind. Eng. Chem. **33:** 1046 (Aug. '41). To study removal of fluoride from natural waters contg. approx. 5 ppm. F, commercial pilot plant charged with 1.3 cu.ft. calcium phosphate complex especially prepd. for F removal, with rating of 358 grains of F per cu.ft. 50 runs made with flow rate of 1.5 gpm., ending when F content was 1 ppm., usually after about 17 hr. Avg. F removal 346 grains, and avg. F in effluent 0.42 ppm. Optimum rate of flow 1.5 gpm. for set-up used, and 1.4 lb. of NaOH in 1% soln. needed for each regeneration. Approx. 0.65 lb. of phosphate lost in 50 runs totaling 83,700 gal. water, indicating need for phosphate replacement of 5% every 300 cycles. Munic. installation large enough to treat 7 mgd. would need 6,200 cu.ft. of phosphate, 6,600 lb. of 90% NaOH and 2,500 cu.ft. of carbon dioxide (for removing last traces of caustic from phosphate after regeneration with NaOH). Raw water studied had total hardness of 343 ppm., with Mg:Ca ratio of 57 to 43. Using F removal equip. to follow lime-soda softening, less material would be needed for F removal. [Not clear what period of time used as basis of calcg. NaOH and $CO_2$ required.]—*Selma Gottlieb.*

**The Removal of Fluorides From Water by Ionic Exchange.** R. E. Benson, D. L. Porth and O. R. Sweeney. Proc. Iowa Acad. Sci. **47:** 221 ('40). Fluoride soln. of 10 ppm. F in tap water passed in series through 2 beds of exchange material. First bed, Zeo-Karb H (Permutit), replaced alkali metals in soln. with H, according to equation: $2NaF + H_2Z = H_2F_2 + Na_2Z$. Effluent then passed through bed of Nalcite B, an ionic exchange material (Natl. Aluminate). Resin removed HF according to equation: $2R_2N + H_2F_2 = 2R_3NHF$. As this method reduced F concn. to only 2 ppm., procedure further altered by passing soln. of NaF through 4 beds in series. First and third beds consisted of 60 ml. each of Zeo-Karb H, while second and fourth, of 60 ml. each of Nalcite B. Results obtained show that F content can be reduced by double ionic exchange to less than permissible value of 1 ppm. allowed by many health authorities. In detg. F content, 100-ml. portions of effluent anald. by colorimetric Sanchis method.—*C.A.*

**Recent Developments in the Phosphate Field.** Henry W. Easterwood. Ind. Eng. Chem. **34:** 13 (Jan. '42). Among other developments is application of alkali meta- and polyphosphates to water softening, where advantage is taken of complex formation between the phosphates and calcium and other alk. earth ions. Tetrasodium pyrophosphate has in last 3 or 4 yr. become ingredient in leading soap powd. compns., serving, when present in sufficient quants., to sequester all of Mg and some of Ca so that they do not react with soap. Ca soap when formed is in such dispersed condition that it will not deposit on fibers of cloth being washed. 1 lb. of tetrasodium pyrophosphate releases approx. 2.2 lb. of soap for detergent purposes; when used in normal hard waters, 20 to 30% of soap can be saved by inclusion of 10 to 15% of it in soap compn. Unlike trisodium phosphate, however, it is not alk. enough to act as detergent alone.—*Selma Gottlieb.*

**Sodium Aluminate, Its Production and Use.** H. Siegert. Angew. Chem. (Ger.) **53:** 250 ('40). Sodium aluminate formed as intermediate product in mfr. of alumina by alk. decompn. processes. White product, readily soluble in water, and alk. in reaction. Made up of

alumina and soda in ratio of 1:1.2 to 1:1.3; excess of alkali stabilizes product. Known that removal of magnesium from water difficult as magnesium hydroxide tends to remain in colloidal form in water. Addn. of sodium aluminate helps pptn. of compd.; may be used in combination with lime-soda softening process. For removal of silica from boiler feed water sodium aluminate may be employed; sodium aluminum silicates pptd. Sodium aluminate may be used with advantage in chem. treatment of sewage as it does not produce acidity, does not form colored compds. with hydrogen sulfide, easy to handle, and does not corrode equip. In treatment of swimming pool water, use of sodium aluminate as coagulant preferable to use of aluminum sulfate as it does not produce acidity. By adding sodium aluminate, mixing, and filtering, water almost free from org. matter and contg. no iron or manganese obtained. In open-air baths, use of sodium aluminate prevents development of green algae as free carbon dioxide removed from water by alkali. For removal of turbidity and color from raw water, sodium aluminate and aluminum sulfate can be added at same time. Flocs formed by two salts have opposite charges and pptn. therefore assisted. Sodium aluminate can be used alone or with iron and aluminum sulfates for removal of oil from boiler feed water. Also used for purifying lubricating oils, for impregnating textiles, and in sugar and paper industries. Activated alumina or alumina gel has high adsorbent capac.; prepd. by treating aluminum salts, usually sodium aluminate, with acids or acid salts. Activated alumina used for many purposes including removal of org. and inorg. turbidity and slime from water.—*W.P.R.*

**Tetrasodium Pyrophosphate.** Andreas Treffler. Soap. **17:** 11: 29 ('41). In neutral solns., water-softening eff. of sodium metaphosphate about 7 times as great as tetrasodium pyrophosphate (TSPP.); in alk. solns. only 4 times as great, and at higher temps. it decomposes slowly in neutral solns. and more rapidly in alk. solns. Tetrasodium phosphate remains unchanged during boiling and its water-softening and detergent strength improved by alkalies. Table given, showing titration of tap water (1.6 grain hardness), contg. 0.2 ml. std. soap soln., with 5% TSPP. solns. and other alkalies, alone and mixed in different proportions, to permanent lather lasting 5 min. at 20°C. Addn. of even small amt. of TSPP. readily produced permanent lather in all cases.—*C.A.*

**Relative Assimilation of Fluorine From Fluorine-Bearing Minerals and Food (Tea), and From Water and Food.** Margaret Lawrenz and H. H. Mitchell. J. Nutrition **22:** 621 ('41). Fluorine of NaF, administered in drinking water at low levels, 21% more completely assimilated by rats than fluorine of same compd. consumed in same amts. in food. Where cryolite source of fluorine, depression in assimilation brought about by admixt. with food was 20%.—*C.A.*

**Rapid Titration of Chlorides by the Volhard Method.** Roger K. Taylor. Chem. Analyst **31:** 1:6 (Feb. '42). Volhard titration of chlorides consists of addn. of excess std. $AgNO_3$ soln. to sample, filtration and washing to remove pptd. AgCl, and back-titration of excess $AgNO_3$ in filtrate by means of std. thiocyanate, using ferric alum as indicator. Expeditious procedure is to add ferric alum indicator to somewhat acid soln. of sample, introduce few drops of thiocyanate (sufficient to give decided red color) and then, with stirring, titrate rapidly with $AgNO_3$ until red color completely disappears. Surprisingly close to true end-point. Few more drops of $AgNO_3$ added to ensure excess, ppt. coagulated by agitation, filtered out and washed, and filtrate titrated to end-point, only small amt. of thiocyanate being required. Washing of ppt. need not be extensive since only very small excess of $AgNO_3$ present. Alternatively, filtration may be omitted if AgCl inactivated by adding nitrobenzene and shaking vigorously.—*R. E. Thompson.*

**Recovering Silver Nitrate From the Residue Remaining After the Determination of Chlorine.** V. Ya. Tartakovskiĭ. Zavodskaya Lab. (U.S.S.R.)

**9:** 1:112 ('40). Add HCl (d. 1.19) to flask contg. residue in amt. equal to 5% of total vol. of liquid, let stand 12 hr. and siphon off clear soln. Wash several times with hot HCl (1:4) by decantation until colorless soln. obtained and 1–2 times with water, and filter through Büchner funnel. Add 3.5 l. water to 2.5 kg. pressed-out AgCl, add gradually, in course of 3 days, 60 g. thin Zn shavings, let beaker stand 2–3 wk., keeping vol. of liquid at 3.5–4.0 l. Add 10–15 ml. HCl (d. 1.19) at intervals of 2–3 days (total vol. of acid should not exceed 60–80 ml.). Siphon off $ZnCl_2$ soln. when nearly all Ag is sepd. in form of metallic Ag. Treat residue with 1:1 HCl soln. with heating and const. stirring, wash twice with warm, dil. HCl, and with water, and filter on Büchner funnel. Dissolve metallic Ag in $HNO_3$ (d. 1.14), filter, evap. on water bath until appearance of film and crystallize out at 50–60° in drying oven. Approx. 10 kg. $AgNO_3$ and some residue contg. Ag obtained from 12.5 kg. pressed-out residue contg. 30% water. Time required for recovery of Ag 56 hr. (excluding time required for galvanic pptn. of Ag). Cost of reclaimed $AgNO_3$ approx. 5% of market value.—*C.A.*

**Automatic Control of the Chlorine Content in Water.** A. I. SIROTINA. Hig. i Sanit. (U.S.S.R.) No. 9: 27 ('39); Khim. Referat. Zhur. (U.S.S.R.) No. 5:99 ('40). Residual Cl detd. photoelectrically by ortho-tolidine (colorimetric) method. Two bundles of rays from same lamp fall on photoelec. cells of identical sensitivities. Bulb. contg. std. colored soln. placed in path of 1 bundle of rays and diaphragm in path of 2nd bundle. Difference in photoelec. currents produced by 2 bundles of rays falling on cells produces displacement of galvanometer needle. Intensities of bundles can be equalized by regulating opening of diaphragm until galvanometer needle reaches zero position. Deg. of closing of diaphragm is index of intensity of rays passing through bulb with std. soln. Blank test with bulb filled with water made to det. absorption of light by color of std. alone (exclusive of absorption by walls of bulb and by water). Scheme for automatic control of chlorination of water developed, including control of ortho-tolidine, automatic sound, light and graphic indication of excessive content of residual Cl and automatic anal. of water. —*C.A.*

**Dissolved Oxygen Recordings With the Dropping Mercury Electrode.** ROBERT S. INGOLS. Ind. Eng. Chem.—Anal. Ed. **14:** 256 (Mar. '42). Arrangement described, records D.O. concns. on recording thread galvanometer and is adapted to lab. or outdoor use. Instrument, from Cambridge Instrument Co., N.Y. City, uses simple potentiometer circuit with sensitive, suspension, mirror galvanometer to measure current flow in dropping mercury electrode circuit. Light beam impinging on mirror reflected to photoelec. cell; resulting current amplified and recorded at 1-min. intervals with recording thread galvanometer. Calomel half-cell used as inert reference electrode; dropping mercury electrode consists of separatory funnel with long stem and short length of 0.04-mm. bore capillary tubing to give drop rate of approx. 1 drop per sec. For outside use, both encased in steel shell for protection, and long, heavy, high-conductance cable used to connect electrodes to instrument. Applications to study of activated sludge process of sewage treatment described.—*Selma Gottlieb.*

**The Determination of Small Quantities of Oil in Water.** C. P. PRINGLE. J. Soc. Chem. Ind. (Br.) **60:** 173 ('41). Method described for detg. content of oil in condensed water returned to power plant for use as boiler feed water, by extracting oil with benzene. Benzene forms emulsion when shaken with large proportion of water, but emulsion can be broken up by generating hydrogen within sample. 2.5 l. of sample shaken vigorously at intervals for 15 min. with 100 ml. benzene and 50 ml. concd. hydrochloric acid. Magnesium wire, wound on glass rod, placed in liquid for 15 min.; wire removed and sample allowed to become clear of bubbles of hydrogen. Benzene layer sepd., washed and dried, and benzene distd. off. Oil dried at 100° until constant weight obtained. Accuracy of method within 0.4 ppm. and 93–95% of solvent can be recovered—*W.P.R.*

## BACTERIOLOGY

**A Modification of the Routine Dilution Tests and Tables Showing the Most Probable Number of Organisms and the Standard Error of This Number.** *Also:* **A Consideration of the Accuracy of Estimation of the Most Probable Number of Organisms by Dilution Test.** SATYA SWAROOP. Indian J. Med. Res. **29:** 499, 511 (July '41). Papers make further contribution to already substantial "literature." May be of some interest to explain why much written. Originally, expedient of culturing different vols. (or dilns.) of waters suspected to be bacterially contamd. used qualitatively rather than quantitatively. If, when water A sampled, samples of less than 100 ml. usually gave sterile cultures, while for water B, samples as small as 10 ml. gave growths, common-sense inference drawn that B worse than A and more or less arbitrary criteria laid down. But then investigators asked whether, from knowledge of proportion of sterile tubes in series of dilutions, one could deduce no. of organisms per unit vol. of original water. At once difficulties begin. Very easy to calc. chance that, if one draws a sample of 10 balls from urn contg. balls 50% of which are black and 50% white, all 10 will be black. Much less easy to assign limits to proportions in an urn of unknown content when all we have is sample. Indeed impossible unless some hypothesis adopted which can be challenged. Even with two samples, say one of 10 all white, another of 50, one *or more* of which is black, there may be differences of opinion as to procedure. Diln. problem essentially similar from math. standpoint. Main difference between work of earlier writers, such as GREENWOOD AND YULE in 1917 and that of more recent students that latter use more delicate tests of precision and have gone into question of best system of dilns. and allocation of numbers of tubes to minimize error of estd. bacterial density. Author gives reasons for thinking that dilns. of 1/2, 1/10 and 1/100 likely to be practically most useful, and has calcd. no. of tables giving M.P.N. of organisms in 100 ml. of water and its std. error for various combinations of results when 2, 3, 5 or 10 tubes used at each level. Statistical criticism of method might be that, as distributions are skew, extremely so when estd. no. of organisms is small, std. error not very good measure of reliability—density cannot be less than zero and must be positive if *any* tube has given growth—and alternative methods might be better. But always difficulties in making tables for routine use and it is, perhaps, doubtful whether in routine work any high order of precision needed. —*B.H.*

**Reclaiming Agar for Bacteriological Use.** ALDEN F. ROE. Science **96:** 23 (July 3, '42). Treatment gives product actually superior to common commercial agars. Such reclaimed agar has hardness of approx. 100 as compared with 20 to 50, detd. by hardness apparatus (J. Bact. **41:** 48 (Jan. '41); *see* Jour. A.W.W.A. **33:** 1852 (Oct. '41)). Ash content 1% or less compared with avg. 4%. Crude protein N content 1 to 2 mg./g., ½ to ¼ < commercial samples. Also most non-solidifying gum content (30 to 40%) removed. Possible to reduce N content further with pancreatin. Used culture medium sterilized, made slightly alk. to litmus, filtered through cheesecloth and cotton. Cooled slowly until solidified. Sediment layer removed, then agar shredded by passing through wire screen at least 16-mesh. After prelim. washing several hr. in cheesecloth bag by running water to whiten, bag transferred to container for infusion with tap water at temp. not exceeding 50°C., stirring at intervals. Water should contain residual or added Ca salt. Sodium hypochlorite added primarily to prevent bact. growth. Waste filtrate siphoned off, fresh water added at intervals. After 6 to 8 infusions covering several days, excess water drained and traces of hypochlorite and salts removed with dist. water. Either evap. down on steam bath, or freeze and thaw to remove more water, or dry directly in thin layers in oven at 50° to 70°C. and finally at 100°C. When dry, agar pieces may be weighed and soaked prelim. to use or ground to powder in hand-mill. Agar reclaimed from blood-agar and differential media contg. indicators and dyes such as phenol red, E.M.B. and Endo. Latter

should be processed separately, however, and infusions be of acid reaction to intensify bleaching. Glass or porcelain enamel containers preferred. Waste agar quant. should be several or more liters. When insufficient quant. available for processing, may oven- or sun-dry by pouring in thin layers in pans, store dry in bottles. Good practice even in large labs. in case agar becomes unavailable.—*Ralph E. Noble.*

**Reclamation of Used Agar.** Howard I. Thaller. Science **96:** 23 (July 3, '42). After removing bacterial growth, medium in flasks and tubes autoclaved 30 min. at 15 lb. Hot melted medium poured into glass vessels or crocks of greater diam. at top than bottom. Cool slowly to settle solids. When solid, excise sediment layer and re-treat till only sediment remains. Recovered medium forced through ⅛″ mesh screen and placed in 50- to 60-mesh cotton 100-lb. bag (for large amts.). Latter placed on raised screen base in tub or large box with bottom outlet. Rubber hose attached to water faucet and open end inserted in bag center with open bag end tied around. Water made to flow slowly. Knead bag occasionally to remove air and facilitate percolation. Dark brown effluent gradually becomes lighter. Washing continued at least 10 hr., usually over night, when agar becomes grayish white. Agar and effluent Biuert neg. at this point. Washing completed, bag left on stand until most free water content drained. Agar then gently spread on specially prepd. screen trays and placed in drying cabinet for evapn. Plyboard cabinet about 60″ x 19″ x 36″, both ends open, holds 10 evapg. trays 2″ apart so arranged air forced through box baffled to insure even evapn. Trays 18″ x 36″, made of 1″ to 2″ wood frame material, strengthened by median brace. Heavy g-i. ¼″ mesh hardware cloth attached to frame over which placed 16-mesh wire screening. Air forced into box by 16″ circulating fan passing air primarily through steam room-heating element which heats air to approx. 80°C. After about 12 hr., dried agar only slightly darker than original material, crisp and like flattened sponge sheet easily removed. Media prepared from such reclaimed agar tested in other labs. with > 30 different micro-organisms. Results uniformly satisfactory. From several tests, estabd. 75 to 80% treated agar recovered, including initial loss adhering to flasks in pouring.—*Ralph E. Noble.*

**Brilliant-Bile Broth for the Determination of the Coliform Group in Water.** I. S. Ol'kenitski and A. N. Rozenfel'dt. Lab. Prakt. (U.S.S.R.) **15:** 10: 9 ('40). Object of expts. to det. to what extent gas formation on Danham medium signifies presence of coliform group. The Danham medium used consisted of broth (pH 6.9) + lactose 1% + ox bile 2% + brilliant green 1% (1:100,000). Direct inoculations on the brilliant broth also carried out without preliminary inoculation. Non-chlorinated river water with a 0.01–0.100 titer produced gas after 24 hr. on broth with brilliant green (0.1–1.0 ml.). Parallel investigation of river water (non-chlorinated) according to method of Eijkman and with green broth showed that pos. results (presence of coliform bacteria) obtained 221 times by method of Eijkman and 219 times with brilliant-broth method, and that neg. results obtained 28 and 41 times, resp. Brilliant broth acts bacteriostatically on whole water flora, except coliform group. Parallel investigations showed that the Eijkman method does not produce reliable results with chlorinated water. Supposed that, depending on tech. conditions of chlorination (concn. of Cl, duration and conditions of phys. contact, temp. of water, etc.), Cl may produce only bacteriostatic effect. Inoculation of such microbes (in state of bacteriostasis) produces no growth on solid media (either Endo or Levin media), whereas inoculation of same microbes on brilliant broth produced prolific growth of coliform rods and abundant gas formation. Reinoculation on brilliant broth favorable moment for normalization of the culture. Eijkman method produces unreliable results and not recommended for investigating chlorinated water.—*C.A.*

**Incidence of Coliform Bacteria on Fresh Vegetables and Efficiency of Lactose Broth, Brilliant Green Bile 2 per cent and Formate Ricinoleate Broth as Presumptive Media for the Coliform Group.** G. G. Slocum and W. A.

Boyles. Food Res. **6:** 377 (July–Aug. '41). Authors examd. 92 samples of 14 varieties of vegetables from 10 different localities, all purchased from wholesale markets Washington, D.C., and examd. within 4 hr. Estns. made of *Esch. coli* and of coliform organisms. 3 different isolation methods used and data represent composite results. Incidence on vegetables for which 5 or more samples examd is as shown in Table 1. Definitely higher incidence of *Esch. coli* and of other coliform bacteria on vegetables edible portion of which grows within soil, as compared with those with edible parts above soil. No signif. difference found in incidence of coliform organisms on vegetables grown in different areas.—*B.H.*

TABLE 1

*Incidence of* Esch. coli *and Coliform Bacteria on 92 Samples of Vegetables*

| VEGETABLE | NO. OF SAMPLES | ESCH. COLI | | COLIFORM GROUP | | COLIFORM GROUP > 1,000 PER 100 G. | |
|---|---|---|---|---|---|---|---|
| | | No. of positive samples | % + | No. of positive samples | % + | No. of positive samples | % + |
| Lettuce | 25 | 0 | 0 | 12 | 48 | 4 | 16.0 |
| Celery | 24 | 12 | 50.0 | 24 | 100 | 17 | 70.8 |
| Radishes | 7 | 6 | 85.7 | 7 | 100 | 3 | 4.9 |
| Onions | 6 | 2 | 33.3 | 5 | 83.3 | 1 | 16.6 |
| Carrots | 6 | 4 | 66.6 | 6 | 100 | 1 | 16.6 |
| Cabbages | 5 | 1 | 20.0 | 2 | 40 | 0 | 0 |
| Parsley | 5 | 1 | 20.0 | 5 | 100 | 1 | 20.0 |
| Other vegetables | 14 | 3 | 21.4 | 11 | 78.6 | 3 | 21.4 |
| Totals | 92 | 29 | 31.5 | 72 | 78.3 | 30 | 32.6 |

**On Tests of the Significance of Differences in Degree of Pollution by Coliform Bacteria and on the Estimation of Such Differences.** H. J. Buchanan-Wollaston. J. Hyg. (Br.) **41:** 139 (Sept. '41). Detailed math. study made of methods available for estg. signif. of difference in deg. of poln. of water by coliform bacteria, estd. in usual way from no. of positive tubes in lactose broth and of obtaining practically useful estimates of such differences. For estg. signif. of difference in single pair of samples, difference in total no. of fertile tubes (N.F.T.) is employed as variate rather than difference in M.P.N. Table included by which signif. of any difference in N.F.T. may be detd. readily. Application of binomial distribution in testing signif. of consistency in sign of series of differences explained and table included to facilitate application of binomial for series of pairs 20 or less in no. Use of normal distribution as approx. to binomial for pairs over 20 in no. explained. Choice of level of signif. discussed as well as results of application of some statistical tests of signif. to data from control expt. In expt. nos. of each pair of samples taken from same water sample and treated by identical methods. Theoretical bases of tests of signif. of differences in M.P.N. and N.F.T. compared. Advantage of knowledge of exact distribution of single difference in tests of significance of series of differences explained, and examples given which demonstrate advantage very clearly. Also combination of results taken at different times and places for testing signif. of time or locality effects explained and suggestion made as to use of replicated observations when value of *P* for each observation known.—*P.H.E.A.*

**Eijkman Relationships of the Coliform and Related Bacteria.** C. A. Stuart,

ALICE ZIMMERMAN, MURIEL BAKER AND ROBERT RUSTIGIAN. J. Bact. **43:** 557 (May '42). Investigated to det. ability of several genera of family Enterobacteriaceae to grow, produce acid or gas in modified Eijkman medium at 45.5°C. More primitive members, *Serratia* and *Erwinia* frequently killed at this temp. in 24 hr., even from heavy inoculums, but not *Aerobacter*. In their Eijkman characteristics, intermediates much more closely related to *Aerobacter* than to *Escherichia* because former and intermediates seldom produced gas from lactose at 45.5°C. while *Esch.* failed. *Salmonella* strains usually grew, some producing acid, others gas at this temp. In genus *Shigella*, less pathogenic *alkalescens* and *sonnei* produced acid readily while *paradysenteriae* strains for most part failed to grow. Authors suggest trend toward specialization be recognized by making *Serrateae*, *Erwineae* and *Esch.*, tribes I, II, III respectively in family Enterobacteriaceae.—*Ralph E. Noble.*

**A Group of Coliform Bacilli Serologically Related to the Genus Salmonella.** C. A. PELUFFO, P. R. EDWARDS AND D. W. BRUNER. J. Infec. Diseases **70:** 185 (Mar.-Apr. '42). Reference to agglutination of colon and para-colon bacilli by serums derived from typhoid and paratyphoid organisms. In many instances, these coliform bacilli isolated from enteric disease cases and their agglutination by serums of known pathogenic types called para-agglutination. Only recently this agglutination of coliform bacilli by *Salmonella* serums examined more closely from standpoint of antigenic anal. 7 paracolon strains possessing flagellar antigens closely related to those of *S. dusseldorf* and *S. cerro* described. Majority, isolated from diseased animals, composed 5 serologic types of detd. antigenic compn. All bacilli fermented lactose slowly and liquefied gelatin. *Enterobacteriaceae* of biochem. properties not coinciding with any present recognized genera.—*Ralph E. Noble.*

**Investigation of Bacteria of the Salmonella Group in Sewage of the City of Buenos Aires.** RAUL FERRAMOLA AND JOSE J. MONTEVERDE. Bol. Obras. Sanit. Nacion (Arg.) **5:** 615 (Dec. '41). Bact. examn. of 40 samples of Buenos Aires sewage yielded 14 strains of *Salmonella*. After preliminary enrichment in Kauffmann's brilliant green sodium tetrathionate media, organisms isolated by streaking on lactose litmus agar, or on lactose brilliant green agar of Kristensen, Lester and Jürgens. On basis of biochem. and serological reactions, following species identified: *S. anatum*, *S. newport*, *S. derby*, *S. partyphi B.*, *S. give*, *S. bredeney*, *S. london*, *S. minnesota*, *S. typhimurium* and *S. montevideo*. Absence of inhibiting agents in lactose litmus agar permitted salmonellas to develop well, producing pure colonies which facilitated process of identification. In this media, however, *Proteus* colonies sometimes overgrew those of *Salmonella*. In cases of this sort, Kristensen media found advantageous. Majority of salmonellas obtained by transfer from Kauffmann's media after 24 hr. incubation at 37°C. Some strains, however, required up to 120 hr. incubation in enrichment media before isolation obtained.—*J. M. Sanchis.*

**The Incidence of Aer. aerogenes in the Feces of Persons Suffering From Intestinal Infections and Its Significance in Water Analysis.** K. V. KRISHNAN AND A. P. CHAWLA. Indian M. Gaz. **76:** 628 (Oct. '41). Authors describe study of incidence of coliform types in stools of persons suffering from specific intestinal infections. Investigation undertaken especially to find out frequency of *Aer. aerogenes* under these conditions. Incidence in stools from cases of intestinal disorders of unknown etiology 35.3% and in cholera and typhoid cases in the region of 90%. Ratio of *Aer. aerogenes* to total coliform organisms varied from 11.14% in unknown etiological intestinal group, to 27% in cholera group. In some cholera stools 95% of coliform organisms were *Aer. aerogenes*. Types of coliform organisms present in feces examd. arranged in descending order of frequency, as follows:

| | |
|---|---|
| *Esch. coli*, type I | = 77% |
| *Aer. aerogenes*, type I | = 15% |
| *Esch. coli*, type II | = 3% |
| Irregular types | = 2% |
| *Aer. aerogenes*, type II | = 1% |
| Intermediate types | = 1% |

Author claims that from these results *Aer. aerogenes* should be seriously considered as indicator of fecal poln. Quite rightly pointed out that organism also found in other situations than in intestine of man and animals, but until method of differentiating between soil *aerogenes* and fecal *aerogenes* devised, no definite opinion as to true signif. of *Aer. aerogenes* in water can be given. In light of findings, stds. of Ministry of Health should be accepted rigidly and no laxity of such stds., even in tropical countries, appears justifiable.—*B.H.*

**Photoelectric Estimation of Indole.** C. B. Allsopp. Biochem. J. **35:** 965 ('41). Small concns. of indole and its derivs. estd. quickly and accurately with Ehrlich's *p*-dimethylaminobenzaldehyde reagent by use of Hilger absorptiometer equipped with filters giving max. transmission at 440 mμ. Amts. up to 2 mg. indole in 100 ml. of soln. detd.—*C.A.*

**Isolation of a New Species of Dysentery Bacillus.** S. D. Rubbo. Med. J. Australia. **2:** 81 (July 26, '41). Organisms giving identical reactions isolated in pure culture about same time from two individuals, in one instance from enlarged ileocaecal gland in fatal case showing inflammation of large intestine and hepatic abscesses probably due to amebic dysentery; and in other case, also fatal, from pus from peritonitis resulting from perforation of ulcer of ileum, possibly also due to *Endameba histolytica*. Organism a motile Gram-neg. rod producing colonies like those of dysentery bacilli. Produced acid and gas in glucose and sucrose, not in lactose, maltose, mannite or dulcite. Indole formed. Two strains related to one another antigenically but unrelated to other dysentery bacilli or common salmonellas. Author tentatively gives organism name *Shigella dysenteriae* Melbourne, but clear that more evidence must be produced before can be included among organisms causing bacillary dysentery.—*B.H.*

**Study of Freshwater Bacteria. Wray Castle Investigations.** Anon. Surveyor. (Br.) **100:** 218 (Dec. 26, '41). Work summarized in latest annual report of Freshwater Biological Assn. of British Empire. Research planned to provide background of general bacteriology of fresh waters, as essential part of ecological program. Std. technique had first to be adopted. Agar medium contg. sodium caseinate, starch, glycerol and inorg. salts, when incubated at 20°C. for 15 days gave highest counts of bacteria. During summer when water became stratified, counts in upper layers of lakes appreciably higher than in lower layers. Storage of samples at 20°C. found to cause appreciable increase in nos. of bacteria as detd. by plate counts. Good proportion of bacteria in lakes capable of reducing nitrates, but only few able to oxidize ammonia or nitrite, or to fix atmospheric nitrogen. Special attention devoted to coliform bacteria of which fluctuation in nos. did not appear ro be related to fluctuations in total plate counts. Feces of fish examd. for presence of coliform bacteria. Coliform organisms found in some samples. Some preliminary work done on bacteria in mud at bottom of lakes. General types somewhat similar to those in cultivated soil. First subject to be tackled intensively will be apparent relation between rainfall and nos. of bacteria in lake waters.—*H. E. Babbitt.*

**The Effect of Potassium Tellyrute on the Dehydrogenases of *Escherichia coli*.** Emily H. Kelly. *Published in abstract only.* J. Bact. **43:** 643 (May '42). In seeking cause for bacteriostatic effect of potassium tellurite on *Esch. coli*, investigated action of substance on dehydro genases of organism. Formate and lactate dehydrogenases found tellurite-resistant; galactose, levulose, and glucose dehydrogenases inhibited, at least by higher concn. of tellurite. Citrase, pyruvase, glycerophosphorase, glycerase and acetase completely sensitive to tellurite whenever demonstrable in culture. Tellurite resistance of trained strains differed little from untrained. Tellurite-tolerant ones appeared to possess enzymes no more resistant to tellurite action than those of parent strains; nor had they developed new dehydrogenases. Had, however, in many instances, lost dehydrogenases most strongly inhibited by tellurite. Results indicate primary toxic

action of tellurite not on dehydrogenases, as tolerant and susceptible strains alike in response.—*Ralph E. Noble.*

**Bacteriophage as an Index of Water Contamination.** C. L. PASRICHA AND A. J. H. DE MONTE. Indian Med. Gaz. **76:** 492 ('41). Method of examn. of water for evidence of contamn. by human excreta described, based on assumption that presence of bacteriophages active against human intestinal pathogens indicates that sample of water contamd. by individuals who harbor such bacteria. Examns. of 516 samples of water from 4 main sources showed that bacteriophages active against causative organisms of typhoid fever, dysentery and cholera were present in about 50% of samples. *Method:* 25-ml. samples of water (collected in sterilized vacuumized ampoules) added to 50 ml. of nutrient broth of peptone water to which added 1 ml. each of young cultures of smooth strains of *Vibrio cholerae, Eberthella typhosa, B. shigae* and *B. flexneri*, mixts. incubated for 48 hr., 0.1 *N* NaOH added, if necessary, to maintain alk. medium and contents filtered through Pasteur-Chamberland $L_3$ candles. Filtrates tested for bacteriophages by drop method.—*C.A.*

**Absorption pf Chlorine and the Bactericidal Effect of Chlorinating Water in the Process of Its Self-Purification.** N. M. VAKSBERG AND A. Y. ZVENIGORODSKAYA. Vodos. Sanit. Tekh. (U.S.S.R.) No. 11–12: 50 ('39); Khim. Referat. Zhur. (U.S.S.R.) No. 5: 99 ('40). Investigations under lab. conditions indicate that bactericidal effect of chlorination considerable in 1st stage of self-purif. and that decrease in absorption of Cl very small. Sharp rise of Cl absorption in 2nd stage characterized by increase of nitrites. To overcome this, amt. of Cl should be increased. In final stage, oxidation of nitrites to nitrates accompanied by sharp drop of Cl absorption of water.—*C.A.*

**Aquatic Bacteria in Relation to the Cycle of Organic Matter in Lakes.** SELMAN A. WAKSMAN. Univ. of Wis. Symposium Hydrobiol. ('41). P. 86. Role of bacteria in decompn. of org. matter, liberation of essential nutrient elements in available form, and accumulation of bottom humus discussed. Bacterial activity one factor controlling lake productivity. 58 refs.—*C.A.*

**Report of Committee on Bacteriological Examination of Water and Sewage.** N. J. HOWARD, A. G. LOCHHEAD AND M. H. MCCRADY. Can. Pub. Health J. **33:** 49 (Jan. '42). Bact. counts made on 102 samples of water from springs, wells, lakes, rivers and purif. plants in Que. using (1) std. agar, (2) tryptone-glucose-extract agar, and (3) latter with 1% skim milk added. Two plates of each incubated at 37°C. for 24 hr. and 2 at 20°C. for 48 hr. Only minor differences in counts noted, but colonies on (2) often larger and hence more easily counted. Spreaders grew rapidly on (3), resulting in loss of many records. Concluded that (2) can advantageously be substituted for (1) in examn. of Que. waters. Study of cause of false lactose broth presumptive positive tests in progress.—*R. E. Thompson.*

## HYDRAULICS

**Energy Loss at the Base of a Free Overfall.** WALTER L. MOORE. Proc. A.S.C.E. **67:** 1697 (Nov. '41). In this study stress laid upon energy loss or energy dissipation, not only because of importance in itself, but also because it can be used in calcg. flow characteristics which, in turn, det. design. Complications introduced by side contractions and expansions eliminated in effort to approach condition of 2-dimensional flow. Likewise effects of sills and pools not included. When shooting flow in lower channel, energy loss at base of fall most easily investigated, because area being studied unaffected by downstream disturbances. As much as $\frac{2}{3}$ of energy released by fall may be dissipated as jet strikes flat bottom. For small value of $h/d_c$ (e.g., 1.5) only $\frac{1}{5}$ of energy dissipated ($h$ = height of fall; $d_c$ = hydrostatic critical depth). With given

discharge and fall height, more effective dissipation may be achieved by increasing width of overfall section and thereby reducing value of $d_c$. In all runs, noted that depth of water behind fall considerably greater than in downstream channel. Investigation showed ventilation sufficient to maint. atmospheric pressure behind fall, and indicated rise due to some other cause. Presence of standing water behind fall explained by change in horizontal momentum as water strikes channel floor. Knowledge of presence of standing water behind fall and of its depth should be of value in making stability calcns. of drop structure. Series of runs made with tailwater adjusted to form hydraulic jump at toe of fall. Vertical elements of jump checked closely with momentum equation of Bakhmeteff:

$$\frac{d_2}{d_1} = \frac{1}{2}\left[-1 + \sqrt{1 + B\left(\frac{d_c}{d_1}\right)^3}\right]$$

in which $d_1$ = depth of water at toe of fall before jump and $d_2$ = depth of water after jump. Possible to combine exptly. detd. energy loss with std. hydraulic jump equation to calc. min. depth of tailwater required to form jump. When energy loss at base of fall neglected, jump calcd. may give tailwater depth as much as 20% high. In some instances this will provide desirable factor of safety against jump being washed downstream. Any addnl. safety factor may cause submergence and impair effectiveness of jump as energy dissipater. Comparison made of longitudinal profile of jump with results given by Bakhmeteff and Matzke. Velocity measurements and energy summations show that kinetic energy in undershooting jet is dissipated by time surface profile indicates max. depth. Possible to obtain min. tailwater depth necessary to support jump for any relative fall height. If design tailwater depth chosen a little high, structure should perform satisfactorily over wide range of discharges. Investigation made to det. effects of increasing tailwater until jump completely submerged. By plotting velocity energy in high-velocity jet against distance downstream, found that increasing submergence caused high-velocity jet to persist for greater distance. Oversubmergence of jump may require bottom protection to be extended farther down channel. Findings of study may be summarized: (1) Loss of energy head at base of fall neither negligible nor const., but varies over considerable range as function of relative fall height. (2) Depth of water standing behind fall greater than depth of water shooting from base of fall and may be computed from momentum principle. (3) Momentum equation for hydraulic jump may be applied to flow conditions at base of fall to det. vertical elements of jump. (4) Velocity energy of undershooting jet spent by time surface profile indicates end of jump. (5) Free overfall 2-dimensional drop structure will perform satisfactorily over wide range of discharges. *Discussion. Ibid.* **68:** 187 (Jan. '42). Author points out that flow conditions below overfall completely detd. if amt. of energy lost in transition known. He measures this energy loss in model and gives curve showing relation between $\frac{E_1}{d_c}$ and $\frac{h}{d_c}$, in which $E_1$ is total flow energy below fall (expressed as head). Shown that for large drops, energy loss considerable. Water in lower sheet flows into bottom of standing pool, causing clockwise rotation, while comparatively still water passes from pool into the jet at exactly same rate. This mixing responsible for loss of energy. As result of mathematical anal., can be shown that:

$$\frac{d_1}{d_c} = \frac{\sqrt{2}}{1.06 + \sqrt{\frac{h}{d_c} + \frac{3}{2}}}$$

Total energy of discharging fluid is found by means of relation

$$E_1 = d_1 + \frac{V_1^2}{2g}$$

Then

$$\frac{E_1}{d_c} = \frac{\sqrt{2}}{1.06 + \sqrt{\frac{h}{d_c} + \frac{3}{2}}}$$

$$+\frac{\left(1.06+\sqrt{\frac{h}{d_c}+\frac{3}{2}}\right)^2}{4}.$$

—*H. E. Babbitt.*

**Viscosity and Surface Tension Effects on V-Notch Weir Coefficients.** ARNO T. LENZ. Proc. A.S.C.E. **68:** 351 (Mar. '42). Purpose of tests to obtain exptl. data with regard to effect of viscosity and surface tension on weir coef., $C$. Found that coef. increases with both viscosity and surface tension, and decreases with increase in head and angle of V-notch. Comparison of published coefs., from similar tests with water, with values of $C$ computed from general equation, shows agreement within about 1% for all weir angles between 28° and 90°. Effect of angle of notch largely eliminated by use of formula: $Q = C \frac{8}{15}\sqrt{2g}\tan\frac{\theta}{2}H^{2.5}$. $C$ is a dimensionless function of Reynolds' and Weber's nos. May be computed from: $C = 0.56 + \frac{B}{\mathbf{R}^n W^m}$ in which Reynolds' and Weber's nos. defined by: $\mathbf{R} = \frac{g^{0.5}H^{1.5}}{\nu}$ and $W = \frac{\rho g H^2}{\sigma}$.

Coefs. $B$, $m$, $n$ have const. values for given angle of notch and may be computed from: $B = 0.475 + 0.225 \div \left(\tan\frac{\theta}{2}\right)^{0.80}$, $n = 0.165\left(\tan\frac{\theta}{2}\right)^{0.09}$, $m = 0.170 \div \left(\tan\frac{\theta}{2}\right)^{0.035}$. In above eq. for $C$, value of Weber's no. must exceed approx. 300; for water head should preferably be greater than 0.2′ and liquid must not cling to downstream face of plate. Reynolds' no. must exceed critical min. value of $300\Big/\left(\tan\frac{\theta}{2}\right)^{0.75}$. $C$ remains const. for all values of $\mathbf{R}$ and $W$ beyond that at which min. $C$ occurs. Min. values for published test data are within 1% of 0.585. Equation applicable for angles 28° to 90° and has been found true for 10° and 20° V-notches. Head-discharge eq. is: $Q = \left(2.395 + \frac{N}{H^e}\right)\tan\frac{\theta}{2}H^{2.5}$. Comparison with data by other experimenters satisfactory. Change in viscosity and surface tension when temp. of water increased from 40° to 70° F. sufficient to cause decrease in computed discharge coef. of 0.34%. Increasing temp. from 40° to 165° F. decreases computed $C$ about 1%.

*Nomenclature:* $B$ = a coef.; $B_1$, $B_2$, .. $B_x$ = const. coefs. for any weir angle; $C$ = V-notch weir coef.; $C_1$ and $C_2$ = const. weir coef. for large values of $\mathbf{R}$ and $W$, respectively, equal to 0.56; $C_x$ = const. coef. for values of $\mathbf{R}$ and $W$ = 0.56; $e$ = const. exponent for any given weir angle; $g$ = gravity const.; $H$ = hydraulic head, in ft.; $m$ = const. coef.; $n$ = const. coef.; $N$ = const. coef. for any given weir angle; $Q$ = flow, in cfs.; $\mathbf{R}$ = Reynolds' no.; $W$ = Weber's no.; $\theta$ = notch angle; $\nu$ = kinetic viscosity; $\rho$ = density of liquid; $\sigma$ = surface tension.—*H. E. Babbitt.*

**Graphic Solution of Fluid-Friction Problems.** E. S. DENNISON. Engineering (Br.) **153:** 179 (Feb. 27, '42). Data in any general case of fluid friction commonly presented in form of diagram in which friction coef. appears as function of Reynolds no., both to log scales. Data can be applied to phys. circumstances which may be widely different from those of original expts. Frequently required to find soln. in terms of some variable, e.g., veloc., which appears both in friction-coef. group ($\psi$) and in Reynolds no. group ($\mathbf{R}$). Paper describes graphical procedure to solve $\psi$-$\mathbf{R}$ eq. directly in terms of required variable.—*H. E. Babbitt.*

**The Venturi Flume Flow Meter.** A. LINFORD. Civ. Eng. (Br.) **36:** 582 (Oct. '41). Weirs suffer from 2 serious drawbacks—considerable difference of level, i.e. head loss, is obtained and silting may take place upstream. Venturi flume is now used universally under circumstances where weir would be unsatisfactory. Principle of flume similar to that of Venturi tube. In following discussion, linear dimensions expressed in ft., velocities in fps., rates of flow in cfs., and energies in ft.-lb./sec. units per lb. of water. In flow through Venturi flume total energy loss is equal to head

loss, due to friction, plus increase in kinetic energy. When depth of flow const. and surface of water parallel with channel invert: $l - \frac{fQ^2p}{2ga^3i} = 0$ or $i = \frac{fV^3}{2gm} = h_f$, in which $l$ = length over which friction head $h_f$ is measured, $Q$ = rate of flow, $p$ = wetted perimeter, $g$ = acceleration due to gravity, $a$ = cross-sectional area of flow, $i$ = slope, $f$ = coef. of friction, $V$ = velocity, and $m$ = hydraulic mean depth. Under condition where $\frac{dh}{dl} = \infty$ $l - \frac{Q^2w}{ga^3} = 0$ in which $w$ = free surface width, or $Q = \sqrt{\frac{ga^3}{w}}$. When water has min. total energy content, $\frac{dE}{dh} = 0$ and $l - \frac{Q^2w}{ga^3} = 0$. Depth and velocity at which relationship obtained referred to as "critical." For any given specific energy (total energy referred to base of channel) 2 possible depths of flow. Owing to drawdown effect, critical depth obtained some distance upstream from backdrop. At greater depth, velocity less than critical and as total energy decreases in direction of flow, depth decreases and velocity increases until critical value $v = \sqrt{\frac{ga}{w}}$ reached. Another condition is that due to slope of channel; velocity greater than critical and flow at lower depth obtained. In this instance standing wave formed. Similar hydraulically to sudden expansion in closed pipe. For calcg. height of wave, momentum equation must be applied. Expressing pressure + momentum by $N$, in general terms, $N = \frac{Q^2}{ga} + ax$, where $x$ = depth of center of section below surface. Hence, $\frac{dN}{dh} = -\frac{Q^2w}{ga^2} + a = a\left(l - \frac{Q^2w}{ga^3}\right)$. In Venturi flume, let subscript, $_1$, refer to upstream and subscript, $_2$, refer to throat, then $Q = a_1v_1 = \frac{Cd\sqrt{2g}\, a_1\sqrt{h_1 - h_2}}{\sqrt{\left(\frac{a_1}{a_2}\right)^2 - l}}$, in which $Cd$ = coef. of discharge. Formula will be recognized as standard Venturi tube flow formula with important difference that cross-sectional areas of flow $a_1$ and $a_2$ vary with $h_1$ and $h_2$, i.e. with rate of flow. By applying theory of varied flow through open channels Venturi flume may be so constructed that rate of flow is function of $h_1$. If throat is made of such width that $h_2 + \frac{V_2^2}{2g}$ and hence $h_1 + \frac{V_1^2}{2g}$ is greater than total energy on downstream side at all rates of flow within required range of registration of meter, critical depth of flow will be obtained at throat where $v_2$ will equal $\sqrt{\frac{ga_2}{w}}$; in other words, substituting this value of $v_2$ in equation $h_1 + \frac{v_1^2}{2g} = h_2 + \frac{\ }{w_2}$ which is greater than $h_3 + \frac{V_3^2}{2g}$, where subscript, $_3$, refers to downstream (below throat). When this condition is obtained flume stated to be working under "free" flow conditions. For free discharge conditions

$$Q = \frac{C_d\sqrt{2gh}\, W_1 h_1\sqrt{h_1 - yh_1}}{\sqrt{\left(\frac{W_1 h_1}{W_2 h_2}\right)^2 - l}}$$

$$= \frac{C_d\sqrt{2g}\, W_1 h_1^{3/2}\sqrt{(l - y)}}{\sqrt{\frac{E^2}{y^2} - l}}$$

$$= C_d\sqrt{2g}\, W_1 h_1^{3/2}\sqrt{\frac{g^2(l - y)}{E^2 - y^2}}$$

in which $W$ = width of rectangular channel, $\frac{h_2}{h_1} = y$, and $\frac{W_1}{W_2} = E$. $2E^2 - 3yE^2 + y^3 = 0$. Graphical solution of this eq. for $y$ is recommended. When value of $E$ is large, $y = \frac{2}{3}$ and $Q = Cd\sqrt{2g}W_2h_1^{\frac{3}{2}}\sqrt{\frac{\frac{4}{27}}{l = \frac{4}{9E^2}}}$ or approx. $Q = 0.385\, Cd\sqrt{2g}W_2h_1^{\frac{3}{2}}$. For value of $E$ of 4 or more, approx. formula gives error less than 2%. Venturi flumes of cross-section

other than rectangular do not lend themselves to simple relationship between upstream depth and rate of flow. If at any fixed rate of flow downstream depth is gradually raised (say by closing penstock), as downstream depth increases wave approaches throat and decreases in height, limiting condition being when wave reaches throat and disappears. Further increase of downstream depth will increase energy content above that at throat and consequently backing up throughout flume will take place, both throat and upstream depths increasing and throat velocity decreasing below critical. Value of $y$ will also alter. Under these conditions flow through flume will become "drowned." Formula now written

$$Q = \frac{Cd\sqrt{2g}\,E\,W_2\,\frac{h_2}{y}\sqrt{h_1 - h_2}.}{\sqrt{\left(\frac{E}{y}\right)^2 - l}}$$

Drowned conditions may be obtained when downstream energy is only 80% of throat energy, because of eddy effects. To prevent drawdown effect in throat it must have certain length of parallel. If parallel streaming not obtained, formulas will not be applicable between this section and upstream. Measuring point of upstream depth must be some distance upstream, say equal to one-half to one upstream depth. If tranquil conditions are obtained upstream of approach, no standing wave will be formed and flume record will be accurate. Even when math. considerations show that wave will form in channel upstream of approach, still necessary to ascertain approx. position to ensure reasonable flow conditions upstream. This involves integrating expression:

$$dl = \frac{l - \frac{Q^2W}{ga^3}}{i\left(l - \frac{fQ^2p}{2\,ga^3i}\right)}$$

$dh$. Recommended that integration be performed by finite increments. Most convenient material of constr. of Venturi flumes is concrete. Throat section must be constructed with particular care to specified dimensions. Small Venturi flumes, say 6″ upstream width and less, may be cast iron, throat section lined with stainless steel. Upstream pressure tapping may be either pipe or slot extending full depth of channel. Recording mechanism practically always of float type. When concrete float well used with no external glass gage, zero may be set with hook gage.—*H. E. Babbitt.*

**Flow in Rivers and Canals. Essentials of a Good Formula.** ANON. Wtr. & Wtr. Eng. (Br.) **44:** 10 (Jan. '42). In note presented to Central Board of Irrigation, India, Dr. J. K. Malhotra quotes E. E. Morgan who considers that formula to be used should satisfy: (1) accuracy within limits of practical design over reasonably wide range of $R$ and $s$, (in which $R$ = hydraulic radius and $s$ = slope); (2) capable of being applied to various conditions of channel surface; and (3) simple to use. He selected Manning's formula for prepn. of his tables because it: (1) is accurate as any known formula; (2) is well known; (3) has same values of $n$ as Kutter's formula; (4) is equally accurate as Kutter's formula; (5) is simple to apply. Although Kutter's formula is best for large rivers with flat gradients, Manning's is more convenient to use and is equally if not more accurate for ordinary purposes.—*H. E. Babbitt.*

**Flow in Pipe Networks by Direct Determination.** JAMES A. CONKLIN. Eng. News-Rec. **127:** 370 (Sept. 11, '40). Procedures for detn. of flow in networks frequently begin with pure assumptions as to quantity flows from which tentative loss-of-head calcns. made. Adjustments then made in loss-of-head calcns. and then applied to the quantities. Method presented by which first step—with regard to flow volumes—may be made by direct computation as preliminary basis for study, thus simplifying procedure.—*R. E. Thompson.*

**An Engineer's Approach to Fluid Mechanics.** ARTHUR ELLWOOD. Eng. News-Rec. **127:** 505 (Oct. 9, '41). Review and discussion, largely math., of some of new concepts developed by Prandtl-von Kármán school and of phys. signif. of various formulas of modern "fluid mechanics." No math. derivations included, since these can be found in 8 references given.—*R. E. Thompson.*

**Chart for Balancing Pipe Head Losses by the Hardy Cross Method.** George M. Slight. Eng. News-Rec. **128:** 41 (Jan. 1, '42). Alignment chart which greatly reduces labor of applying Hardy Cross method to balancing head losses in pipe networks described. Chart, which can be constructed in about 3 hr. is, for most part, more accurate than slide rule. Prepn. of chart and use detailed.—*R. E. Thompson.*

**Analyzing Flow From Multiple Reservoirs by the Hardy Cross Method.** J. F. Muir. Eng. News-Rec. **128:** 408 (Mar. 12, '42). Hardy Cross method may be applied to problem of flow distr. from no. of elevated storage reservoirs supplying water to distr. main. Flow equations become unwieldy when algebraic methods employed for computing flows from 3 or more reservoirs discharging through compd. pipe into distributing main, whereas in Hardy Cross method no complex math. relations involved and labor, other than reading tables and charts, consists only of simple arithmetic. Application of method to 3-reservoir problem illustrated.—*R. E. Thompson.*

## HYDROLOGY

**Development of the Science of River Measurement Hydrology.** John C. Hoyt. Civ. Eng. **12:** 324 (June '42). Science of hydrology, of which river measurement important part, deals with factors that det. behavior of water from time it falls on earth until it returns to atmosphere or disappears as ground water. First historical personage to apply scientific principles for use and benefit of fellow men, and to leave written record, was Heron of Alexandria, who lived in Second Century B.C. Heron shows clearer understanding and better practice than appear 200 yr. later in Roman writings on subject. Little further development in hydrology until era of Leonardo da Vinci (1452–1519 A.D.). His understanding of hydraulic laws indicated by reasons he gave to acct. for variations in discharge from canal through orifice. Not until Seventeenth Century, under influence of Galileo (1564–1642) and mainly through his two pupils, Castilli and Torricelli that the science of hydrology began again to progress. In 1775 M. Chezy, celebrated French engr., developed formula known by his name: $V = c\sqrt{RS}$. This first algebraic expression of law of moving water. Interest in hydrology started in U.S. between 1840 and 1850, when Humphreys and Abbott started investigations of Mississippi River and tributaries. Although many have contributed to development of science of hydrology, present status has resulted largely from lead given by engrs. of U.S. Geol. Survey. —*H. E. Babbitt.*

**Evaporation Loss From Land Areas.** David Lloyd. Wtr. & Wtr. Eng. (Br.) **44:** 135 (June '42). Evapn. loss is amt. of water vaporized in given period of time by process of evapn., whether continuous, intermittent or at varying rates. Not practicable to measure evapn. loss over land areas, but measurements of rainfall and runoff show deficit largely created by evapn. Other factors influence loss. Movement of water from clouds as rain thence in streams to ocean before being revaporized called hydrologic cycle. Ground water effluent joins earlier surface flow and is measured in total runoff. Measurement made from free water surfaces and from satd. porous surfaces which measures so-called evapg. power of air. Amt. transpired by plants measured by botanists under controlled conditions. Appears that amt. of evapn. from land surfaces under natural conditions not greatly increased by crops; that evapn. rate controlled by heat flow; and that total evapn. from soil water also dependent on rainfall characteristic. As ground-water effluent moistens subsoil and soil in vicinity of streams, etc., essential controlling factors of evapn. are vol. of effluent and climate. C. W. Thornthwaite and B. Holzman developed a rational formula for detg. evapn. power of air from observations of moisture concn. and wind velocity in turbulent

layer of air above land surface. During recent years, author has published inferences obtained by statistical anal. of data of apparent loss on some large drainage areas. Apparent loss found indirectly as residual and hence importance of assessing rainfall and measuring runoff accurately. At drainage area where underground impermeable and negligible ground water, total evapn. loss will be practically wholly soil water evapn. loss. Such areas found on Pre-Cambrian and Lower Silurian rocks. Annual soil water evapn. loss in in. expressed by:

$$0.57R^{.87} + 1.10(T - 48) + 0.006(S - 1{,}450)$$

where $R$ = in. rainfall of a year; $T$ = mean air temp. in °F. and $S$ = hr. duration of sunshine in year over area. Each

TABLE 1

*Inferred Ground Water Evapn. Loss*

| GEOL. FORMATION UNDERGROUND | AVG. ANNUAL LOSS | GEOL. FORMATION UNDERGROUND | AVG. ANNUAL LOSS |
|---|---|---|---|
| Alluvium | 9″ | Carboniferous | 4″ |
| Drift | 9″ | Devonian | 3″ |
| Cretaceous | 8″ | Silurian, Upper | 3″ |
| Triassic | 7″ | Silurian, Lower | 1″ |
| Permian | 6″ | Pre-Cambrian | 0″ |

term of expression gives result in in. units. Author aware of other factors influencing evapn., but contends that in such phenomena of multiple effects primarily necessary to find principal controls. Use of inferred relations to est. total loss at an area simple, though assessment of ground water evapn. loss will require some experienced judgment respecting permeability of underground. Procedure would be: (1) detn. of rainfall value; (2) assessment of temp. avg. over area; (3) assessment of sunshine; (4) estn. of soil-water evapn. loss in annual period from eq.; (5) estn. of ground water evapn. loss from Table 1—in case of rainfall below 30″ or above 60″ some adjustment will be necessary; (6) addn. of ests. 4 and 5; (7) to make a comparison with apparent loss already obtained indirectly by gaging, addn. of effects of rainfall from previous months. Errors involved are due to no. of factors, some inherent in any empirical association and several due to points already mentioned. If, on other hand, such an empiricism enables an imperfect est. to be made, it is surely better than present state of approximations.—*H. E. Babbitt.*

**A Direct Method of Flood Routing.** C. O. WISLER AND E. F. BRATER. Proc. A.S.C.E. **67:** 1053 (June '41). Method of flood routing, successful use of which depends only on availability of dependable stream-flow records during typical flood at various points on main stream or on tributaries whose flow is to be routed downstream. Routed flows show extent to which each of upper tributaries contribute to flood peak at each downstream point. Entire procedure based on storage equation and on principle that, for all high stages, there is a straight-line relationship between vol. of storage contained in any reach of river channel and sum of inflow rate at upper end and outflow rate at lower end of that reach. In all studies in which proposed to secure improved conditions by reducing flood peak through use of reservoirs, by reforestation, or by means of other than local protective measures, such as levees and flood walls, essential to know to what extent each of several tributaries contributes to resulting flood peak. Clearest presentation of method can be made by means of illustrative example. First operation described is derivation of hydrograph of inflow into intervening area between Fetterman and Morgantown (W.Va.). First step in soln. lies in detn. of hydrograph of channel inflow from intervening area. If $I$ represents avg. inflow from intervening area, then

$$I = \frac{S_1 + O_0 + O_1 - (S_0 + Q_0 + Q_1)}{2}$$

in which $Q_0$, $O_0$ and $S_0$ represent, respectively, discharge at Fetterman, outflow at Morgantown, and storage in intervening reach, all at beginning of period considered, and $Q_1$, $O_1$ and $S_1$ same quants. at end of period. Next step is detn. of hydrographs at Morgantown

resulting from: (1) discharge at Fetterman, and (2) inflows from intervening area. To test method for different types of stream pattern and shapes of drainage basin, two other routings made, both on Shenandoah R. At Lynnwood sum of routed flows agrees almost perfectly with actual records. At Front Royal agreement not so good, although not poor. Accuracy of results that can be obtained by this method of flood routing depends almost entirely on availability of: (1) good stage-discharge relationship curves at various points on stream, and (2) actual flood record. With these data at hand either known flood or any hypothetical flood can be routed downstream. *Discussion. Ibid.* **67:** 1763 (Nov. '41). W. B. LANGBEIN: In their presentation authors seem to overlook fact that floods routed daily and expeditiously by empirical methods. Authors refer to comparison between two methods of computing volume of inflow. Appears to writer that the two methods are one. Has been shown that, in general case, unless proper weights assigned to inflow and outflow, discharge-storage relation was a loop. Straight-line relationship between weighted discharge and storage approxd. by many reaches. Convenient, but not necessary corollary to general flood-routing technique, and not proof of authors' general statement that overland flow ceases and channel storage-drainage begins at time of point of contraflexure on recession side of hydrograph. Method of verification adopted by authors may be deficient to extent that data used in derivation of technique may have sampled only limited no. of experiences. FRED E. TATUM: Method advanced by authors for obtaining storage curves saves considerable time. Curve thus obtained represents true storage for that particular storm rather than avg. curve as computed by other methods. Authors went to considerable trouble in computing local inflow and then routing it down to gage, when it is readily obtainable by easier method. H. C. WOSTER: Method of flood routing as developed by authors distinct contribution to methodology of delineating flood and damage source areas. Results obtained by using regular run of discharge records less fortunate than those encountered by authors. Necessary in most cases to adjust routed hydrographs of $Q$ and $I$ after completion of procedure, because when they are combined they do not check actual hydrograph. Application of authors' channel storage relationship reduces peak discharge in transit between stations less than actually occurs. Also, actual time of transit of flood wave greater than that obtained by this method.—*H. E. Babbitt.*

**Surface Runoff Determinations From Rainfall Without Using Coefficients.** W. W. HORNER AND S. W. JENS. Proc. A.S.C.E. **67:** 533 (Apr. '41). (*See* Jour. A.W.W.A. **33:** 1289 ('41). *Discussion. Ibid.* **67:** 1180, 1469 (June, Oct. '41). L. L. HARROLD: Description of application to design of storm sewers. C. E. RAMSER: Method especially appropriate to storm-sewer design. Simplification possible, particularly in connection with estimation of runoff from agric. areas, where, quite often, cost of improvement would not justify large expense involved in detailed anal. LEROY K. SHERMAN: Authors' procedure of correlating period of observed rain intensities with curve of infiltration capac. practical requirement in application of infiltration theory. They have described, in detail, phenomena and procedure of computing surface runoff from small areas—predicated on use of curves of infiltration capac. Little space given to methodology for deriving this curve. No mention made, in paper, of derivation or use of avg. areal infiltration capac. Attempts made by writer and others to make direct use of avg. areal infiltration capac. or "avg. loss rate" values without subsequent derivation of curves of infiltration capac. or loss rates. Such attempts, based on avg. from unrelated storms, have been futile and misleading. A. J. SCHAFMAYER: Method of arriving at rate of runoff from given area by deducting rate of infiltration into soil, plus other losses from rainfall intensity rate, interesting departure from former methods. To apply authors' method, necessary to det. infiltration capac. and overland flow for particular areas entering into specific problem. Application for local studies

will probably consist of calcns. for runoff, using rational formula with coef. of runoff, and checking and comparing results with results obtained by other methods. C. S. JARVIS: Both authors' procedure and objective obtained subject to challenge. Conceivable that assumption involved in application of this method to less-favored extensive areas by less skilled technicians may include greater errors and uncertainties than some of more familiar devices. Assertions, such as authors', that empirical formulas and devices unscientific and outmoded, including use of coefs., do not seem to eliminate them from practice nor from preferred equip. where basic data either meager or broken. Main divergence of opinion herein expressed has to do with statement that method generally applicable to all drainage basins. To attempt expansion to cover all drainage basins seems to be attempt at covering targets entirely beyond effective range of small-caliber weapons. Writer has repeatedly gone on record to effect that microscopic approach, unduly emphasized, has contributed to general neglect of great mass of hydrologic data, and of their readily recoverable values. Seems to be more reasonable, if not more scientific, to accord due consideration to observation, experience, and readily understandable empirical expressions that summarize such experience. G. W. MUSGRAVE: That runoff coefs. are misconception has been shown by several workers. Authors have indicated no. of factors that affect infiltration capac., such as soil porosity and surface slope. Effect of antecedent rain upon infiltration is matter of great interest to hydrologists at present. Antecedent rain does much more to soil and soil structure than fill voids with water. Impact of rain drops such as to apply large amt. of energy to surface of soil. In addn. to mech. effects, of course, many other effects of antecedent rains. At present hydrologists may be measuring merely "shadows" of true causal factor—pore-size distr. Ordinarily: (1) seasonal trends of soil moisture and soil temp. tend to be correlated inversely; (2) infiltration lower when soil moisture higher, but magnitude of reduction not proportional to increase in moisture; (3) subsoil moisture often shows more marked effect on infiltration than does soil moisture in surface; (4) seasonal trends statistically significant; and (5) continuing evidences that other factors in addn. to that of soil moisture exerting their effects on rate of infiltration. F. L. FLYNT: More rational to consider runoff as rainfall minus losses than to assume that runoff may be expressed as const. percentage of rainfall for given storm. Evident that refinements introduced into design procedure, through more complete understanding of fundamental principles involved, tend to increase work required to design given drainage system, but this is not valid argument against use of improved method. In anal. of streamflow hydrographs, fundamental principle of considering runoff as rainfall minus losses rather than as ratio or coef. rapidly coming into general use. Principle of breaking down area tributary to point of measurement into simpler components for purpose of anal. and synthesis of runoff hydrographs of general application and, no doubt, will eventually become std. practice as will evaluation of runoff as rainfall minus losses instead of in terms of percentage factors formerly used. *Ibid.* **68:** 280 (Feb. '42). ALBERT S. FRY: To be regretted that paper deprecates past work in hydrology and glorifies infiltration as new method that puts hydraulic design on parity with structural steel design in exactness. Large water projects involve extensive works. Doubted that more logical and dependable design for these works can be made by substituting infiltration for previously used methods. Authors' statement that infiltration procedure allows "use of much lower factors of safety than one involving choice of coefficient of runoff" not in accord with established facts. Until engr. can know, with certainty, max. storm expected, no basis for expecting infiltration anal. to justify lower safety factors. Authors recommend aerial photographs for land-use information. Unwary and unknowing would be led to believe that with aerial photographs and soil maps it is simple matter to classify land-use and soil characteristics of drainage basin sufficiently

for satisfactory application of infiltration. Infiltration has definite and most useful application in field exemplified by water-control operations of large system of multi-purpose reservoirs in Tenn. Valley. In this work of daily river-flow predictions and water-control operations, infiltration has large possibilities. Where infiltration may acct. for considerable part of rainfall, method affords logical approach to problem of estg. runoff.—*H. E. Babbitt.*

**Method of Predicting the Runoff From Rainfall.** RAY K. LINSLEY JR. AND WILLIAM C. ACKERMANN. Proc. A.S.C.E. **67:** 1023 (June '41). Writers have anald. hydrological and meteorological records of Valley River Basin in N.C. to develop rational method of predicting runoff based on avg. rainfall and evapn. from std. land pan. Rainfall occurring over natural river basin assumed to be disposed of as follows: (1) Surface loss is that part of rain intercepted by vegetal cover and natural or artificial retention basins from which it eventually evaps. and is thus prevented from entering stream channels. (2) Field-moisture loss that part of rain absorbed in upper layers of soil where it remains until removed by evapn. or transpiration. (3) Surface runoff is that part of rain which travels across ground surface to nearest stream channel and thence to main river system. (4) Ground water accretion is that part of rainfall which percolates through soil to ground water level. Total loss for each storm studied computed by subtracting measured runoff from observed avg. rainfall. To aid in complete separation of hydrographs by storms, following curves developed: ground water recession curve, surface-runoff recession curve, rate of change in flow curve, and ground water vol. curve. Several relations developed that can be used to predict ground water hydrograph on forecasting work: total runoff *vs.* ground water runoff, ground water runoff *vs.* net peak ground water flow, and duration of rainfall *vs.* "time to ground water peak." Anal. of stream flow having been completed, possible to compute total runoff from each individual storm and to det. total rainfall lost. Among conclusions may be included: (1) Methods of stream-flow separation presented satisfactory for Valley R. (2) Accumulated evapn. from std. evapn. pan index of field-moisture deficiency. (3) Surface loss varies approx. with amt. of rainfall and appears to approach practical max. for high rainfalls. (4) Methods of estg. runoff presented represent distinct refinement over rainfall-runoff relations in which such third variables as initial flow, ground water flow, or days to last rain used as criteria of runoff. (5) Further study of parallel nature indicated to det. how these relations vary for other types of basins and for other seasons of yr. *Discussion. Ibid.* **67:** 1603 (Oct. '41). BERTRAM S. BARNES: Writer's belief that authors' scheme calls for more precise separation of elements of flow, in which personal judgment of computer not so important. In this discussion, assumed that any simple recession of hydrograph of one element of flow is curve in form: $Q = Q_0k^t$, in which $Q_0$ and $Q$ are values of discharge at two instants separated by time interval $t$, and $k$ is depletion factor for element of flow. Depletion factor defined as ratio of a given discharge to that which occurred one time unit previously. True, of course, that evapn. and transpiration from water and land surfaces will affect hydrograph noticeably at times of low flow. One great advantage of using depletion factor is that effect of losses largely eliminated from calcd. vol. of runoff. Vol. of runoff $R$, measured on a recession of element of flow expressed as: $R = \dfrac{-Q}{\log_e k}$. Depletion factor $k$ evaluated by taking values of $Q$ at any two points on recession. $\text{Log } k = \dfrac{(\text{Log}Q_1 - \log Q_2)}{T}$, in which $T$ is elapsed time between two points selected. Writer believes that suggestions contained in this discussion will not only simplify work required in forecasting by methods similar to that presented by authors, but will also eliminate, to large extent, errors arising from personal judgment in separating

elements of flow. Authors' procedure of separating initial loss into two parts—surface loss and field-moisture deficiency—and comparing latter with losses from evapn. pan, is distinct departure from any previous practice known to writer. *Ibid.* **67:** 1768 (Nov. '41). RICHARD VAN VLIET: To det. interception and depression storage separately, study of storm rainfall pattern required. Cannot be done with any degree of success by considering only total amt. of storm rainfall and duration. Use of term "surface-runoff recession curve" by authors to express "channel storage," deemed unfortunate, as term "channel storage recession curve" generally used to express this quant., since surface runoff has ended. Seems to writer that any attempt to correlate total duration of rainfall with time for ground water to reach peak will give results of little value if total duration of rainfall includes period of residual rainfall. LEROY K. SHERMAN: Quant. of moisture in soil materially governs intake of rainfall and consequently affects quant. of surface runoff. Authors have not made use of more recent concepts of infiltration theory, such as rainfall excess, recession curve, and mass curve of infiltration capac. Further research, on derivation of initial soil moisture, along lines suggested by authors, much needed in applied hydrology. *Ibid.* **67:** 1935 (Dec. '41). FRANKLIN F. SNYDER: Writer believes that author's "surface loss" really accretion to soil moisture and that loss classified as addn. to field moisture probably initial or surface loss. Difficult to understand how this surface loss by evapn. can be 4 times observed evapn. from pan or how there can be enough natural or artificial surface retention basins to store 2.07" for later evapn. Also some question as to general applicability of empirical value of 0.05" per hr. max. possible absorption. Indicates that rate decreased with continuation of frequent rains.—*H. E. Babbitt.*

**Reliability of Station-Year Rainfall-Frequency Determinations.** KATHARINE CLARKE-HAFSTAD. Proc. A.S.C.E. **66:** 1603 (Nov. '40). (See Jour. A.W.W.A. **33:** 1287 (41).) *Author's Closure. Ibid.* **68:** 145 (Jan. '42). Widespread use of station-year method by hydrologists necessitated means of obtaining measure of persistence in such data and, consequently, of reliability of frequencies detd. by method. Also led to adaptation of technique described in paper. Outlook of progress in climatic and hydrologic research by use of statistical anal. would be dark if method could not be used on observations possessing persistence. Although high intensity rains have occasionally been observed to result from horizontal convergence alone, with no clearly defined fronts in vicinity, by far the greater number of occurrences of high intensity rains are associated with passages of fronts or with convective activity. Hydrologist needs to know much more about size of areas receiving various depths of pptn. in rainstorms, and about relations between intensities and total amts. that actually occur in storms and those that are recorded by various spacings of rain gages. Correct definition of pluvial index is "that amt. which may be expected to occur or to be exceeded . . . on an avg. of once in the frequency cited." Although very little known concerning distr. of rainfall amts., there is evidence to support assumption that they form some type of exponential distr. The eq. $f(x) = e^{-x}$ used to clarify distinction between value of variable $x$ (pluvial index) corresponding to mean recurrence interval $T$, and most probable max. and mean max. values of $x$ in equivalent interval. Mode, $u$, of distr. most probable max. value and will be given by soln. of eq.

$$\frac{T-1}{F(x)} f(x) + \frac{f'(x)}{f(x)} = 0$$

This leads to result $u = \log_e T$. At least for type distr. $f(x) = e^{-x}$ for any given recurrence interval, $T$, corresponding value, $K$, exactly equal to mode, or most probable value, of probability distr. of largest value of $x$ for

equivalent time interval. Value $K$ corresponding to mean recurrence interval, $T$, is $K = \log_e T$. Also most probable max. value, $u$. Mean max. value $\bar{u}$ in $T$ trials is $\bar{u} = \log_e T + c$.—*H. E. Babbitt.*

**Recording Rainfall Gage Designed for Remote Mountain Station.** WALTER J. WOOD. Eng. News-Rec. **127:** 503 (Oct. 9, '41). Rainfall records in Sierra Madre Mts. near Los Angeles of considerable importance to Los Angeles County Flood Control Dist. No. of possible rainfall stations rather limited due to scattered locations of camps and to few permanent resident observers available. Usually when observer moves out, it is necessary to abandon station, but when this occurred at Sleepy Hollow Ranch in Big Tujunga Canyon deemed necessary to continue record, which is longest continuous record in county (44 yr.). Tilting-type receiver installed connected by 12-mi. circuit to integrating recorder near Mt. Wilson. Tilting-bucket unit, with capac. of 0.02" of rain per tip, mounted inside std. type rain gage. At receiving end, by means of heart-shaped cam, rotated by impulses sent out by each tip of bucket, pen on recorder rises in steps of 0.02" until it reaches top of chart, which represents 3" of rainfall; then starts downward traverse of 3". No. of possible traverses unlimited, and entire season's record possible without attention other than winding of clock and changing of charts at recording end, provided, of course, batteries, etc., do not fail. Elec. counter records no. of bucket tips as check against recorded no. at other end of circuit. Std. rain gage also maintd. as check on total amt. of rain recorded. Capac. of gage nearly 24" of rain, evapn. being reduced by film of kerosene over water surface. Equip. designed and constructed by John V. Frederick and F. H. Mellen.—*R. E. Thompson.*

## Obtaining Higher Priority Ratings

A new procedure for obtaining higher priority ratings for materials to complete projects already under way is now effective.

Previously, when a contractor could not complete his construction work because certain materials had not been delivered, and delivery was being held up because the original priority rating no longer was high enough, the contractor applied for a higher rating on Form PD-1A.

Now, application for higher priority rating need not be made on Form PD-1A. Correct procedure is to write a letter in quadruplicate in which is listed all material items requiring a change in preference rating status. Thus, requests for changes in ratings can now be made in one application, whereas previously a separate PD-1A form had to be made out for each class of items.

In compiling the list of materials in the single application, under the new procedure, however, applicants are requested to itemize the materials in accordance with the PD-200A materials list.

The letter should also include information showing builder's serial number, item number, unit of measure, quantity, price, and use of item; latest delivery date permissible, and preference rating required by the supplier to meet the delivery date.

An amendment is then made to the original application.

[The establishment of this system was formally verified by a letter from B. J. Sickler, Deputy Chief, Power Branch of WPB, on August 18, 1942.]